NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

282 750

62-4-5

Enclosure (1)
024-3504

ADVANCED ARMY AIRCRAFT INSTRUMENTATION SYSTEM

REPORT Nr. 1

CONTRACT Nr. DA-036-039SC-87354

TECHNICAL REQUIREMENT SCL-5804 DATED 26 AUGUST 1960

FIRST QUARTERLY PROGRESS REPORT

PERIOD ENDING JUNE 30, 1962

U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY,

FORT MONMOUTH, NEW JERSEY

DOUGLAS AIRCRAFT DIVISION • LONG BEACH, CALIFORNIA

DOUGLAS

QUALIFIED REQUESTORS MAY
OBTAIN COPIES OF THIS REPORT
FROM ASTIA

DOUGLAS AIRCRAFT COMPANY, INC. EL SEGUNDO DIVISION EL SEGUNDO, CALIFORNIA

ADVANCED ARMY AIRCRAFT INSTRUMENTATION SYSTEM

REPORT No. 1

CONTRACT Nr. DA-036-039SC-87354

TECHNICAL REQUIREMENT SCL5804 DATED 26 AUGUST 1960

FIRST QUARTERLY PROGRESS REPORT

PERIOD ENDING JUNE 30, 1962

A pictorial aircraft cockpit display will be installed in a J-50 Beechcraft Twin Bonanza for U. S. Army Signal Corps evaluation

J. N. Cahow
Prepared by:

E. L. Witte
Approved by:

1.0 TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF EXHIBITS

26. HU-1A Scope Drawing
27. J-50 Weight and Balance
28. HU-1A Weight and Balance
29. Purchase Specifications - Generator, Inverters, VOR/LOC, DME
30. Schedule
31. Automatic Terrain Following Proposals
32. Automatic Flight Path Following Proposal
33. SCAT System Installation Proposal
34. Forward-Looking TV Camera Installation Proposal
35. Scope - AAAIS and Supplementary Installation
36. Increased D-Mode Capability

2.0 PURPOSE

This report and its enclosures, Exhibits 1 through 30*, constitute Item 1, "Design Plan for the Pictorial Aircraft Cockpit Display", of the U.S. Army Signal Corps Contract No. DA-36-039 SC 87354. Under this contract Douglas Aircraft will furnish an aircraft instrumentation system based on the latest state-of-the-art concepts of the Army-Navy Instrumentation Program and applicable to a wide variety of aerodynamic vehicles, including fixed wing, rotary wing and V/STOL aircraft. The system will be installed in a J-50 Beechcraft Twin Bonanza aircraft and delivered to the U.S. Army Signal Corps for evaluation.

This report is a general summary of the design plan for that system and is supplemented by detail in the exhibits. Exhibits 31 through 36* are proposals to include desirable additional capability.

In addition to the above Item 1, this contract includes:

- Item 2: An engineering test model of the display system
- Item 3: Installation of the engineering test model in an L23D or equivalent aircraft and flight test
- Item 4: Spare Parts list
- Item 5: Furnishing of engineering services during the Army flight test evaluation of the system
- Item 6: Technical reports

* NOTE: Information concerning specific exhibits, listed in the list of exhibits and referenced herein, is available on a need-to-know basis by applying to the Commanding Officer, USASRDL, Fort Monmouth, New Jersey, Attention: SIGRA/SL-SVN.

3.0 ABSTRACT

The system described in this report has been configured to comply with the U.S. Army Signal Corps technical requirement SCL-5804 as amended contractually and via technical discussions prior to and during the design plan phase of the AAAIS program.

The program design objective as stated in SCL-5804 has been to develop "an advanced flight instrument display using the concepts developed by the Army-Navy Instrumentation Program (ANIP). This program is in support of the ASR-2 and ASR-3 aircraft programs. When provided with adequate sensors this equipment shall have, as a goal, self-sufficient all-weather aircraft operations from remote areas."

Studies related to implementation of the ASR-2-60 and ASR-3-60 program missions indicate that precise self-contained navigation, inflight data processing and optimization of sensors, displays, and controls is required. These requirements result from the necessity for provision of effective crew and system performance under all-weather battle conditions. The same requirements imply the use of system elements capable of handling high data rates with great precision in real time.

With the provision of suitable sensory devices, it is expected that the display system mechanization described herein will directly support the requirements implied by the ASR-2-60 and ASR-3-60 program.

The system will be installed in a civilian equivalent to the L23D aircraft (a J 50) in accordance with SCL-5804 and delivered to the Signal Corps for evaluation. The HU-1A helicopter is considered

as an alternate test vehicle. Installation of the system in a test vehicle has superficially affected some components. However, the design of the display system is universally applicable to a wide variety of high and low performance aerodynamic vehicles. It will meet the display requirements of future aircraft, and will demonstrate a significant improvement over present instrumentation in the test vehicle.

This report and its enclosures, Exhibits 1 through 30, summarize and define the detail design of the Advanced Army Aircraft Instrumentation System.

3.1 PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

(a) Publications - None

(b) Lectures - None

(c) Reports

Monthly Performance Reports

1. Douglas Aircraft Company ltr B-30-AIDS-02 dtd 9-22-61
2. Douglas Aircraft Company ltr B-30-AIDS-03 dtd 10-6-61
3. Douglas Aircraft Company ltr B-30-AIDS-04 dtd 11-6-61
4. Douglas Aircraft Company ltr B-30-AIDS-05 dtd 12-1-61
5. Douglas Aircraft Company ltr C2-30-AIDS-06 dtd 1-5-62
6. Douglas Aircraft Company ltr C2-30-AIDS-07 dtd 2-1-62
7. Douglas Aircraft Company ltr C-71-AIDS-08 dtd 3-7-62
8. Douglas Aircraft Company ltr C-25-1265 dtd 5-8-62
9. Douglas Aircraft Company ltr C-71-AIDS-11-dtd 5-29-62

(d) Conferences

	Date	Place	Organizations Represented	Subject Discussed	Conclusions
1.	14-15 Aug 61	Ft. Mon.	USASRDL-DAC	Organization of AAAIS Program & GFP-CFP	Design Plan criteria was established. Preliminary GFP-CFP equipment list was formalized.
2.	30 Aug 61	DAC	USASRDL-DAC	Universal application of the AAAIS.	The system is basically universal. A study is necessary to determine the systems direct applicability to helicopter.
3.	12-13 Sept 61	Ft. Mon.	USASRDL-DAC	Applicability of AAAIS to Rotary Wing	DAC to submit request for authorization to proceed with rotary wing applicability study.
4.	28 Sept 61	DAC	FAA-DAC	Review of status and objectives of AAAIS program with Mr. Najeeb Halaby of FAA	Mr. Halaby requested to be kept up to date with program.

	Date	Place	Organizations Represented	Subject Discussed	Conclusions
5.	17 Oct 61	Ft. Mon.	USASRDL-DAC	Preliminary review of the fixed wing design plan.	Preliminary review satisfactory. Considered desirable to include rotary wing application pending availability of funds.
6.	23-24 Oct 61	DAC	USASRDL-DAC	Fixed wing aircraft design plan. status	Availability of funds may have a significant effect upon program schedule.
7.	11 Dec 61	Ft. Mon.	USASRDL-DAC	Program review	As a result of partial termination, program to be restricted to submittal of design plan including rotary wing study.
8.	1 Feb 62	DAC	USASRDL-DAC	AAAIS map display	Recognized that additional investigation required to determine map content and to resolve method of map display.
9.	4-5 Apr 62	Ft. Mon.	USASRDL-DOD SIG. CORP & DAC	Detail Review of Design Plan and General Program Review with DOD personnel	Amplification of the Terrain Avoidance Radar aspect is required. Revision of Design Plan to clarify the application to rotary wing aircraft is required.
10.	4 May 62	DAC	USASRDL-DAC	Review Army comments on Design Plan	Design Plan will be returned to DAC for revision and resubmittal.

4.0 FACTUAL DATA - SYSTEM DESCRIPTION

Demands upon the human pilot have increased in direct relation to the increasing performance of aircraft. Since man functions as a link in the man-machine system, over-all efficiency is limited by pilot performance and response time. Improvement of the human element can be achieved only by selection and training of the best-qualified men. Utilization of the optimal man-machine coupling can have much greater impact in increasing the performance of the man-machine weapon.

The achievement of this optimal coupling between man and machine has been the long-range objective of the Army-Navy Instrumentation Program (ANIP). The philosophy of the over-all ANIP includes implementation of the results of the long-range studies into production aircraft systems whenever feasible. Faithful application of this concept through the engineering test model of the Advanced Army Aircraft Instrumentation System will demonstrate that substantial gains in man-machine system efficiency can be realized through the medium of a perceptually simpler integrated display system, and a revised cockpit arrangement. Major contributions can be identified as follows:

* A solution to the spatial orientation problem in the form of the contact analog with flight path. The integrated instrumentation concept permits the pilot to assimilate more information in a shorter time, and obviates excessive pilot head motion and scanning of instruments, thus reducing the frequency of control reversal by the pilot.
* A cockpit arrangement which reduces pilot distraction and improves information acquisition rate.

* An explicit display which reduces the computational work load now carried by the pilot and increases his capacity to accept in-flight diversions from briefed flight plan, thereby increasing tactical flexibility.

* A solution to fuel management problems in maximum range, maximum endurance, or any other altitude and airspeed condition.

* Although it is not intended that this system be incorporated in aircraft on a large scale basis in the immediate future, the system will eventually afford a reduced training time for instrument capability of pilots.

* An increased all-weather capability resulting from the availability of well integrated sensory information.

Display System Features

The cockpit design for the ANIP pilot station includes the proposed primary features as illustrated in Exhibits 8 and 9.

* Primary Displays
* Auxiliary Displays
* Secondary Controls
* Emergency and Warning Indicators

These displays supply in excess of 50% of the information considered necessary for all weather flight and as specified for a 100% implemented ANIP cockpit display. This is roughly a 200% gain over the information supplied by conventional instrumentation presently installed in L23D and HU-1A aircraft. In addition, the information is more effective because of efficient integration.

A complete tabulation of mechanization features, together with a comparison of a 100 percent ANIP system and the requirements of Specification SCL-5804 is presented in Exhibit 1. Figure 1 is a summary of Exhibit 1.

The system design philosophy provides for system applicability to any aerodynamic vehicle, including fixed wing, rotary wing and V/STOL, as shown in Figure 2. Adherence to this philosophy has had minor effects on the central computer in that approximately 5% of the computers capacity is assigned to functions required only by helicopter (autorotation and vertical angle of velocity vector calculations). The terrain radar includes large drift angle stabilization limits required only in a helicopter installation. These two components are the major ones affected by the universal design approach. Cost and weight increases for these two items are considered minor in attaining the design goal.

The details of the system components are as follows:

Primary Displays

1. Vertical Situation Display - Contact Analog with Flight Path, Terrain Clearance, and Velocity Track. The flight path provides for a pictorial representation of flight relative to a command path stabilized with respect to the ground or the air mass. This ground, or air mass, (rather than aircraft) stabilization permits the pilot to fly above, below, to the side, or through this path and thereby observe his positional as well as angular relationship to the desired command. This feature is particularly important during landing approach when a definite singular path to the runway

SUMMARY OF INFORMATION REQUIREMENTS IN EXHIBIT 1

	Total pieces of information required	Percent supplied
ANIP system to meet ASR-2 requirements	167	100
Proposed system applied to J-50 aircraft	88	53
Minimum requirements. SCL-5804	42	25
Proposed system applied to HU-1A	88	53
Standard Fixed Wing Army aircraft (L23D)	32	19
Standard Army Helicopter (HU-1)	29	19

FIGURE I

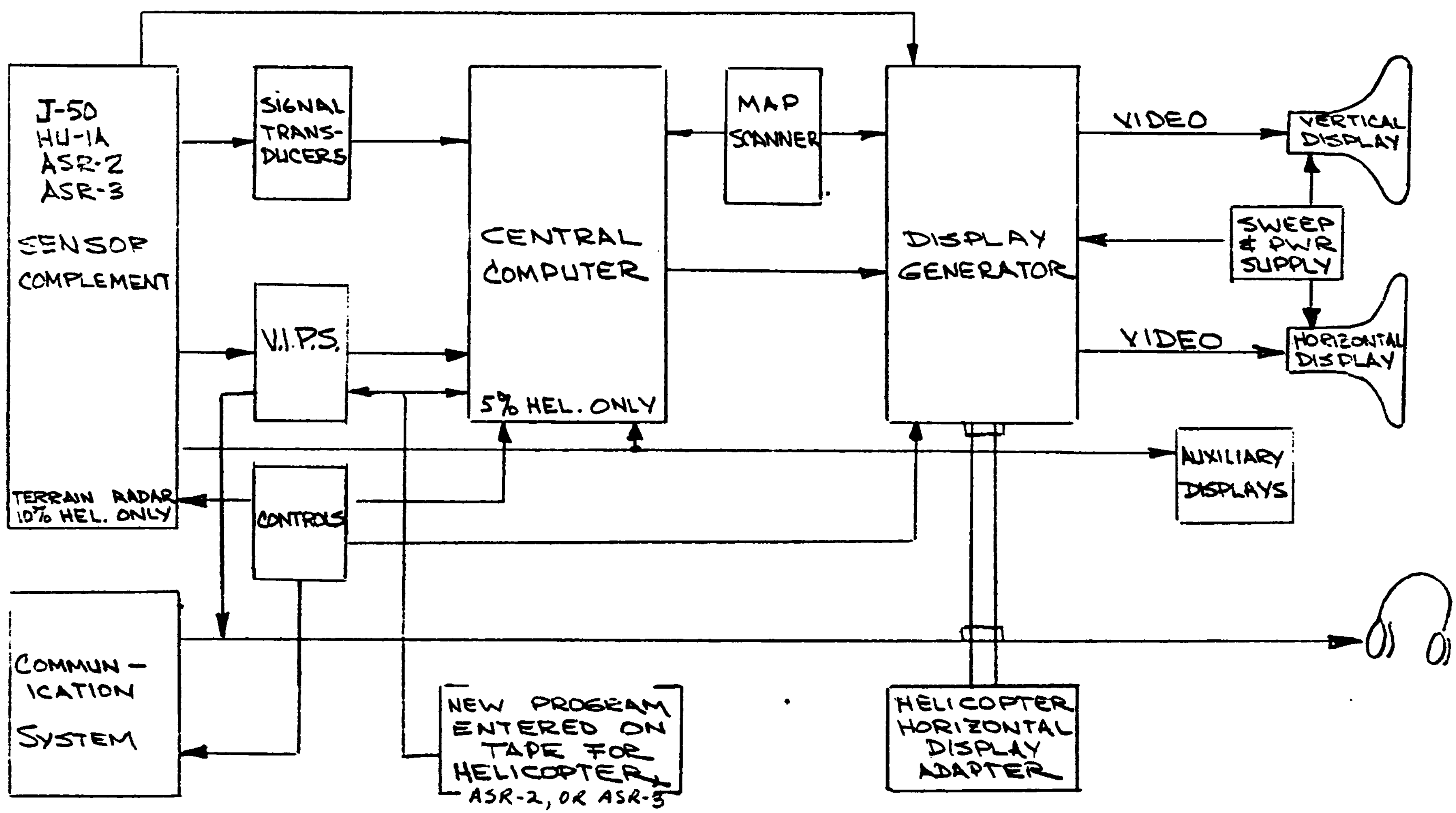


FIGURE 2

UNIVERSAL DISPLAY SYSTEM

BLOCK DIAGRAM

(equivalent to ILS or RAILS) must be vertically and laterally maintained rather than just the correct heading and pitch angles. For evaluation purposes, a three position switch will be provided enabling the pilot to select a "Ground Stabilized Path", an Aircraft Stabilized Path" or an "Air Mass Stabilized Path". The air mass stabilized path provides the same information as the ground stabilized path, with the exception that the path is not positionally corrected for wind. The aircraft stabilized path provides correct heading, pitch, and altitude commands but gives no lateral position information, that is, the near end of the path is fixed to the aircraft in the lateral direction.

2. Horizontal Situation Display - Presenting the map, intended course line, present position, fuel range or autorotation situation, radar mapping or terrain avoidance display. The fuel range and autorotation symbol will be interchangeable, the circle automatically indicating autorotation range only when such a condition is sensed by the radar RPM transmitter. The warning light and voice systems will also, so indicate.

The horizontal display is capable of presenting the Remote Area Instrument Landing Displays should these displays become a requirement.

Auxiliary Displays:

1. Vertical Reading Altimeter and Airspeed Indicators
2. Engine RPM Indicator
3. Engine Gages
4. Engine Manifold Pressure Indicator
5. Cylinder Head Temp.
6. Fuel Quantity Indicators
7. Wheels, Flaps, and Trim
8. Endurance, Time and ETA Counters
9. Auditory Warning and Status System
10. Rotor RPM (HU-1A Only)

Secondary Controls:

1. Flight Mode Selection Panel
2. Cruise Mode Selection Panel
3. Communications Mode Selection Panel
4. Display Control
5. Radar Controls
6. Environmental Control
7. Engine and Fuel Control Panel
8. Automatic Flight Control System Controls
9. Emergency Controls
10. Remote Area Instrument Landing System Controls

Standby and Warning Indicators:

1. Warning Indicators (Obstacle, Wheels, Doppler, etc.)
2. Stand-by Magnetic Compass
3. Altimeter (integral to Auxiliary Display)
4. Airspeed Indicator (Integral to Auxiliary Display)
5. Heading Indicator (Integral to Horizontal Display)

Associated Sensory Equipment:

1. Search/Terrain Clearance Radar
2. Doppler Radar
3. Navigation Radios
4. Vertical Gyro
5. Angle of Attack
6. Compass
7. Fuel Flow
8. Fuel Quantity
9. Air Data
10. Remote Area Instrument Landing System Radar

Central Digital Computer

All data processing and computations required for the complete system are performed by means of a central digital computer. Computer functions include:

* Vertical display symbol displacement commands
* Horizontal display symbol displacement commands
* Navigation computations
* Fuel management computations
* Cruise Control

4.1 Equipment Description

There are three categories of equipment comprising the integrated display system. They are:

1. Government Furnished Property
2. Contractor Furnished Property
3. Provisional

The following paragraphs describe these equipments in general terms. A summary of equipment parameters is shown in Table 1. A detail breakdown of these parameters is shown in Exhibit 2, and technical descriptions of equipments are included in referenced exhibits.

Table 1 also includes a breakout of CFP items which are essential parts of the display system. This breakout tabulates differential weights and sizes of this CFP equipment with respect to that equipment which it replaces in,or is in addition to, the CONUS avionic configuration for an L23D.

4.1.1 Government Furnished Property

Government furnished property is that equipment furnished to Douglas by the U. S. Army Signal Corps for the program. The equipment is listed in Table 1.

4.1.1.1 AN/ASW-12 - Automatic Flight Control System

The ASW-12 Automatic Flight Control System will be installed and made functionally operational. The system is to be GFP and will be connected to the following systems to perform the listed functions:

	SYSTEM	FUNCTION
1.	C-11 Compass System	Heading Hold
2.	C-11 Compass System	Pre-select Heading
3.	AN/APN-118 Doppler	Radar Altitude Hold

4.	344B-1 Instrumentation	Automatic Path Guidance (Omni and Localizer)
5.	51V-3 Glide Slope Receiver	Automatic Path Guidance (Glide Slope)

Other functions or modes of operation of the AFCS are:

1. Yaw Damping
2. Roll Attitude Command (Controller Function)
3. Pitch Attitude Command (Controller Function)

Table I

EQUIPMENT SUMMARY
GOVERNMENT FURNISHED PROPERTY
(J-50 INSTALLATION)

System Name	Size $In.^3$	Wt.Lbs.	A.C. V.A.	D.C. Watts
AN/ASW-12 Autopilot	947	42.8	121	406
C-11 Compass System	900	19.5	95	-
AN/APN-118 Doppler Radar	9,300	65.0	125	224.0
AN/ARC-73	545	45.0	-	205-62
AN ARN-59 A.D.F.	616	20.0	-	79.0
Vertical Gyroscope	207	5.8	37.2	5.9
AN ARC-51X U.H.F. Radio	1,100	32.0	-	255-185
Interphone	576	10	-	22.4
51V3 Glideslope Rcvr.	564	11	-	62.0
R-1041/ARN Marker Beacon Rcvr.	62	1.0	-	2.0
AN/APX-44/IFF (Provision)	-	27.3	-	-
TOTAL	14,817	279.4	378.2	1261.3-1048.3

Table I (Continued)

EQUIPMENT SUMMARY
CONTRACTOR FURNISHED PROPERTY
(J-50 INSTALLATION)

System Name	Size $In.^3$	Wt.Lbs.	A.C. V.A.	D.C. Watts
Digital Computer	2,200	69	270	-
Display Generator	2,295	34	350	59
Vertical Display	2,860	14	-	-
Horizontal Display	1,500	16	-	-
Map Scanner	675	36	76	18
V.I.P.S.	210	4.5	-	60
Airspeed Indicator	120	5.5	-	45
Altitude Indicator	160	8	-	50
T.C.R.S.	4,600	115	900	150
C-11 Power Unit	38	1	-	-
C-11 Mag. Var. Comp.	16	.5	-	-
Angle of Attack	72	2	10	250
Air Data Comp.	54	14	50	70
Fuel Flow	64	2	-	14
344B-1 Converter	765	14.5	26	22
860E-1 D.M.E.	1,300	45	150	14
Temperature Probe	25	.5	-	1
Inverters	819	81	3,000	-
D.C. Generators	1,376	118	-	16,800
TOTAL	19,149	580.5	4,832	17,553

Table I (Continued)

COMPARISON OF ESSENTIAL CFP WITH L23D CONUS CONFIGURATION

Item	AAAIS	L23D (CONUS)	Volume Cu. Ft.	Weight Lbs.
Vertical Display	X		1.55	14.0
Horizontal Display	X		.88	16.0
Display Generator	X		1.25	34.0
Digital Computer	X		1.24	69.0
Terrain Clearance Radar	X		3.20	115.0
300 Ampere DC Generators	X		.45	92.0
3000 VA Inverter	X		.83	61.0
750 VA Inverter	X		.42	25.0
Total AAAIS			9.82	426.0
Altimeter - Indicator		X	.01	1.5
Airspeed Indicator		X	.01	1.0
Gyro Horizon Indicator		X	.02	4.0
Radio Compass Indicator		X	.02	2.0
1-101A-115D-7 3 Phase Inverters		X	.12	12.0
100 Ampere DC Generators		X	.32	55.0
Total L23D (CONUS)			.50	75.5
Differentials			+9.32 Cu.Ft.	+350.5 Lbs.

NOTE: The Collins Model 860 DME (or equivalent) has not been included in the above tabulation since it is a backup navigational aid to be used only for the purpose of system demonstration in the continental United States.

Table I (Continued)

EQUIPMENT SUMMARY
GOVERNMENT FURNISHED PROPERTY
(HU-1A INSTALLATION)

System Name		Size In.^{3}	Wt.(lbs)	V.A.	Watts
AN/ASW-12 A.F.C.S.		1280	55	138	406
C-11 Compass System		900	19.5	95	-
AN/APN-118 Doppler		9300	65	125	224
51V3 Glideslope		564	11	-	62
AN/ARN-59 A.D.F.		616	18.8	-	79
ARN-32 Marker Beacon	*	50	2		
Vertical Gyro		207	5.8	37.2	5.9
Engine RPM	*	30	3		
Rotor RPM	*	30	2		
ARC-55 U.H.F. Comm	*	2500	55		
ARC-44 F. M. Comm	*	900	13		
SB-329-AR Intercom	*	700	12		
APX-44 (Provisions)	*	-	28	-	-
TOTAL		17,077	290.1	395.2	76.9

* Avionic equipment installed in HU-IA per TM55-1520-207-10 dtd 3-61.

Table I (Continued)

EQUIPMENT SUMMARY
CONTRACTOR FURNISHED PROPERTY
(HU-1A INSTALLATION)

System Name	Size In.^{3}	Wt.(lbs)	V.A.	Watts
Digital Computer	2200	69	270	-
Computer Converters	200	6	30	-
Display Generator	2295	34	350	59
Vertical Display	2860	14	-	-
Horizontal Display	1500	16	-	-
Map Scanner	675	36	76	18
V.I.P.S.	210	4.5	-	60
Airspeed Indicator	120	5.5	-	45
Altitude Indicator	160	8.0	-	50
T.C.R.S.	4600	115	900	150
C-11 Power Unit	38	1	125-95	-
C-11 Mg. Var. Comp.	16	.5	-	-
Air Data Computer	54	14	50	70
Fuel Flow	64	1	-	14
51X-2B OMNI	400	10.5	-	34
344B-1 Converter	765	14.5	26	22
860E-1 D.M.E.	1300	45	150	14
Temperature Probe	25	.5	-	1
Inverter	1300	58	3000	-
D.C. Generator	6000	52	-	12000
RAILS	2900	89	-	-
TOTAL	27,682	594.0	4977-4947	12,537

4. Barometric Altitude Hold
5. Engine RPM Control (HU-1A Installation)

The AFCS will not be connected to the Central Computer or Displays for any automatic command or track functions. However, if corresponding modes of operation are selected on the Displays and AFCS, the AFCS should control the aircraft to follow the display flight path with some degree of accuracy. Errors may result because the Displays and AFCS are being fed from different reference sensors.

The following modes of the Displays and AFCS will be comparable:

Displays Mode	Flight Path Selection	AFCS
Air Data (Zero Wind Selection)	Present Course	Heading Hold
Any Nav. Mode	Present Altitude	Altitude Hold (BAR)
Doppler or Nav. Ref.	Bearing Command (OMNI)	Auto Path Guidance (VOR)
Doppler or Nav. Ref.	Landing Mode (Flt. Path)	Auto. Path Guidance (Localizer and Glide Slope)

Some study work has been done with regard to an AFCS - Terrain Radar tie-in. This work is summarized in Exhibit 23.

Further detail on the AN/ASW-12 is given in Exhibit 4.

4.1.1.2 AN/APN-118 Doppler Units

The doppler radar is to be the prime navigational reference for the display system. Two of the engineering test units of the AN/APN-118 system (Transmitter/ Receiver and Electronics Unit) will be used to supply information for the displays. Using pitch, roll, and heading information to stabilize the antenna, the doppler units will generate N-S, E-W aircraft velocities. These velocities will be used by the central computer to calculate aircraft distance traveled and aircraft drift angle. The doppler units will also supply radar altitude information to the auxiliary altitude display and vertical velocity (HU-1A only) for calculation of helicopter vertical angle. A Doppler Fail signal is being used to light a doppler fail light on the vertical display panel.

Further detail on the AN APN-118 is given in Exhibit 5.

4.1.1.3 C-11 Gyrosyn Compass System

The C-11 Gyrosyn Compass is an accurate, light-weight system designed to meet the rigid requirements of polar navigation. The heading information is supplied to the following associated equipments:

1. Horizontal Display
2. Doppler Radar (AN/APN-118)
3. Automatic Flight Control System (NA/ASW-12 AFCS)
4. Very high frequency OMNI Radio Range (344B-1 VOR) unit
5. Heading Select Knob

The C-11 Gyrosyn Compass System has the following components:

1. Thin Flux Valve and Compensator
2. Compass System Rack Assembly
3. Controller
4. C-6 Gyrosyn Compass Indicator
5. Directional Gyro

The Gyrosyn Compass system combines the flux valve and the directional gyro so that the gyro is "slaved" to the earth's magnetic field (eliminating gyro drift) while the gyro's inertia effectively prevents any oscillation of the heading indication.

Further detail on the compass system is given in Exhibit 6.

4.1.1.4 AN/ARC-73 V.H.F. Radio (J-50 Installation Only)

The primary function of the ARC-73 VHF radio is to receive, amplify, and detect VOR and LOC Navigation radio signals. The output of the receiver is applied to the 344B-1 instrumentation unit for conversion to VOR bearing and VOR/LOC course deviation signals. The ARC-73 is also used for VHF two way communication. An aural navigation signal output and communication radio input and output are connected to the headset/microphone by means of the interphone control.

4.1.1.5 AN/ARN-59 A.D.F.

The AN ARN-59 A.D.F. provides airplane to surface station and airplane to airplane bearing information. An output signal provides A.D.F. relative bearing information to the C-6 compass indicator and to the bearing cursor on the horizontal display compass ring. An aural output is provided for surface station identification and for manual direction finding with aural null. The aural signals are connected to the headsets through the interphone control.

4.1.1.6 U.H.F. Radio

The ARC-51X radio set (for J-50 installation) or ARC-55 radio set (for HU-1A installation) provides two way U.H.F. communication. The transmitter input and receiver output are connected to the microphone and headset through the interphone control. A guard receiver is provided for emergency reception on one preset guard channel. The A.D.F. position on the control will not be used.

4.1.1.7 Interphone System

4.1.1.7.1 AN/AIC-12 Interphone System (J-50 Installation only)

The interphone system provides the pilot, co-pilot, and observers with capabilities for intercommunication and selection of desired radio. The following equipment is provided.

1. Pilot's and Co-pilot's station
   a. C-1611/AIC Interphone Control
   b. "Transmit-Off-Interphone" Switch
   c. Headset/Microphone Jack

2. Observers Stations (2)
   a. C-1611/AIC Interphone Control
   b. Interphone Microphone Switch
   c. Headset/Microphone Jack

Each station is capable of receiving UHF and VHF communication radio and navigational radio aural information. The pilot and co-pilot stations only are provided with UHF and VHF communication radio transmitting capabilities. The radio tuning and mode selection controls are accessible only to the pilot and co-pilot. The following capabilities are provided:

1. Communication Radio

▲	a.	AN/ARC-51X	UHF Transmit
	b.	AN/ARC-51X	UHF Receive
	c.	AN/ARC-51X	UHF Guard Channel Emergency Receive
▲	d.	AN/ARC-73	VHF Transmit
	e.	AN/ARC-73	VHF Receive

▲ = Provided at pilot and co-pilot stations only

2. Navigation Radio (Aural Reception)
   a. AN/ARC-73 VHF Nav.
   b. R-1041 Marker Beacon
   c. 860E-1 DME
   d. AN ARN-59 ADF

3. Voice Information Priority System

4.1.1.7.2. <u>Interphone System</u> (HU-1A Installation Only)

The existing HU-1A interphone system will be retained in the helicopter installation. The capabilities are essentially the same as the AN/AIC-12 interphone system.

4.1.1.8 <u>51V3 Glide Slope Receiver</u>

The output of the 51V3 Glide Slope Receiver provides signals for vertical guidance during landing. The output signal provides vertical course deviation information to the AFCS and digital computer, and also positions the glide path pointer on the Course Selector Indicator.

4.1.1.9 <u>Marker Beacon System</u>

The Marker Beacon Receiver signals are converted to an aural output and to an output that controls the Marker Beacon Indicator Light. The Aural Output is connected to the headset through the Interphone Control. An R1041/ARN receiver will be used in the J-50 installation. An ARN-32 receiver will be used in the HU-1A.

4.1.1.10 <u>Vertical Gyro</u>

The Vertical Gyro is installed for the use of the integrated display system exclusively. This allows the aircraft and AFCS to function independent of the integrated display system. The vertical gyro is a Sperry Part No. 1780610, GFP, and supplies roll reference to the AN/APN-118 Doppler, Terrain Clearance

Radar System, Vertical Display, and pitch reference to the Central Computer, Display Generator, and an APN-118 Doppler.

Further detail on the vertical gyro is given in Exhibit 7.

4.1.2 Contractor Furnished Property

Contractor furnished property is the equipment furnished by Douglas for the program. The equipment is listed in Table 1.

4.1.2.1 Vertical Situation Display

The Vertical Situation Display utilizes a 14 inch 90° deflection cathode ray tube.

Final video amplification, horizontal and vertical sweep and high voltage circuits are packaged in the display.

Standard video techniques are utilized and intensity modulated fixed raster video from any source may be displayed. Other forms of video may be displayed on a time sharing basis.

The purpose of the display is to present to the pilot actual and command attitude, altitude, heading and speed. This is accomplished by displaying an artificially generated picture of the real world normally seen under VFR conditions with command information superimposed.

Exhibit 8 contains a preliminary specification for the vertical display.

4.1.2.2 Horizontal Situation Display

The Horizontal Display utilizes a 7 inch round 70° deflection cathode ray tube. Heading and bearing information are displayed by servoed cursors moving over a compass rose which forms a ring around the display tube.

Video techniques utilized in this display are standard and any intensity modulated fixed raster video input may be utilized. Other forms of video may be displayed on a time sharing basis.

The purpose of the display is to provide both pilot and co-pilot with navigation, course, and fuel range information. Additional information for remote area instrument landing is provided for helicopter operation.

Exhibit 8 contains a preliminary specification for the Horizontal Situation Display.

4.1.2.3 Display Generator

The display Generator serves three major purposes; (1) video processing (mixing and shaping), (2) video conversion, and (3) symbol generation.

Video mixing and shaping of all display video, other than RAILS, is accomplished in this unit. The types of video which are mixed and shaped include vidicon picture, electronically generated symbols and converted radar video.

Features of the display generator include:

* Standard televeision raster intensity modulated to insure maximum flexibility.
* Standard television kinescope display tube; otherwise 100 percent transistorized.
* System growth by merely inserting additional circuit cards (no time-shared functions).
* Single low voltage power supply for both vertical and horizontal situation displays.
* Capability of switching contact analog and flight path to either or both display tubes to provide wide field of view for VTOL operations, or in case of failure of vertical display tube.
* System acceptance of image orthicon or IR vidicon inputs for presentation on either display when sensors are available.

Video conversion is done in the radar converter section. This process is one of storing radar video at the radar scan rate and reading it out at the display video scan rate.

Symbol generation is accomplished in another form of video processing wherein analog signals are used to shape, (converting from voltage domain to video time domain), the output form of video generators. All of the various symbols of the displays are, in this manner, controlled in shape, position, motion, and direction.

Mixing of the above mentioned forms of video is accomplished in the final stages of the display generator. This system is readily adaptable to additional inputs and types of inputs.

Exhibit 8 contains a preliminary specification for the Display Generator.

4.1.2.4 Map Scanner

This Map Scanner is a vidcon-scanned Map Storage Device. a selected map area approximately 1,000 miles square, at 2 scales photographically reduced, is stored. The reduction and readout are such that the displayed scales are approximately 1:250,000 and 1:1,000,000. Selected portions of the 1,000 miles square area are photographically reduced from a third scale map and these areas are displayed at a scale of 1:62,500.

The map area to be scanned is determined by positioning of the vidicon and map relative to each other in response to input error commands from the central digital computer. The position of the vidicon with respect to the map is digitally encoded in X and Y, with approximately 17-Bit (1 part in 131,072) resolution in each axis. These encoded position readouts are supplied to the central computer for differencing with the command positions to obtain the command error signals. The command error signals are then transmitted to the map-scanner servos to make actual position equal to command position.

The vidicon output is amplified, shaped, and transmitted to the horizontal display unit.

All sweeps, positioning, and biasing for the vidicon are provided by the display generator, except for final stage amplification.

All map area scan (position) computations are done in terms of the terminal map. Changing of scales according to pilot selection is accomplished in the computer by dividing the terminal map position encodement by 4 for the enroute map or by 16 for the master map. This procedure results in a command position which places the scanned area at the same coordinates on any selected map. The center of the scanned area may be offset from the command position by input of an analog signal which displaces the raster from the center of the vidicon. Since vidicon center is command (or present) position, this procedure allows present position to be displayed off the center of the video display.

Scanned areas are approximately 6 miles across on the terminal map, 24 miles on the enroute map, and 96 miles on the master map.

Exhibit 9 is a preliminary specification for the Map Scanner.

4.1.2.5 Airspeed Status Indicator

The Airspeed Status Indicator is electro-mechanically operated. Vertical scale indicates true airspeed, command airspeed and stall speed. The scale shown in Figure 3 reflects the low speed requirements of the J-50 test vehicle. However, the unit is designed to operate in high performance aircraft also. A new scale with an available gain change is all that is necessary to make this indicator applicable to high performance vehicles.

The inputs associated with Display System equipment are:

INPUT FROM	FUNCTION
Air Data Computer	T.A.S.
Central Computer	Command T.A.S.

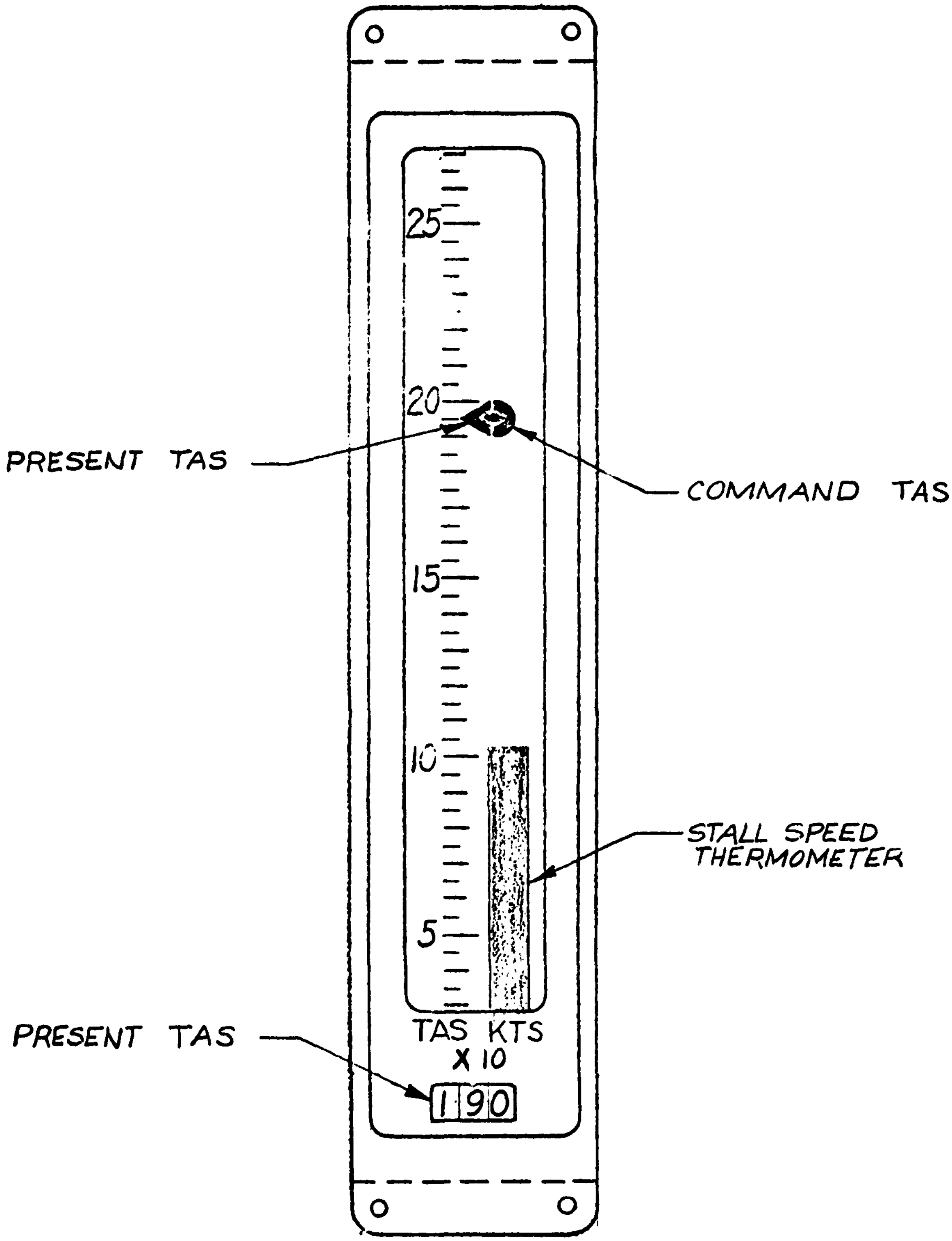
Mechanization consists of 3 servo motors with rate generators, 3 servo amplifiers, 3 control transformer synchros, 1 digital counter, 3 moving tapes and associated gears, rollers and pulleys.

Exhibit 10 is a detail specification for the Airspeed Indicator.

4.1.2.6 Altitude Status Indicator

The altitude status indicator is a vertical scale instrument which presents simultaneous displays of aircraft altitude, terrain altitude, command altitude, preselect/terrain follow altitude and maximum permissible aircraft altitude. The scale shown in Figure 4 reflects the altitude capability of the J-50 test vehicle. However, the unit is designed to operate at higher altitudes. A new scale and an available gain change is all that is necessary to make this indicator applicable

DOUGLAS AIRCRAFT COMPANY, INC. EL SEGUNDO DIVISION EL SEGUNDO, CALIFORNIA



AIRSPEED STATUS INDICATOR
FIGURE 3

ALTITUDE STATUS IND.

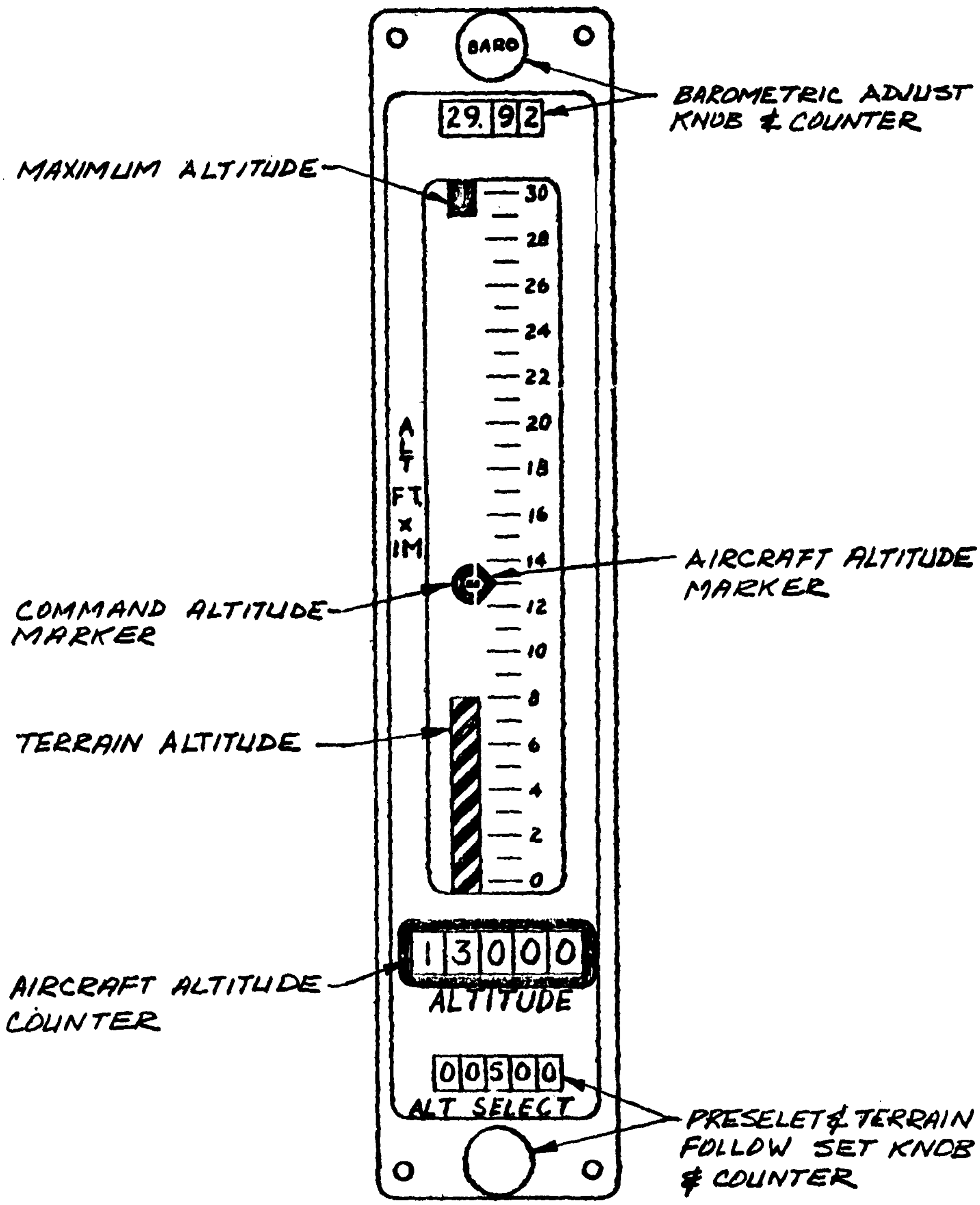


FIGURE 4

to higher flying vehicles.

A vertical rate indicator, although not included in the present design is under consideration. It is a vertical scale instrument which presents climb and descent rates up to 20,000 feet per minute by means of a moving pointer and moving tape. The pointer indicates that the tape readout is used for rates of climb or dive exceeding 1500 feet per minute as shown in figure 5.

INPUTS

FROM	FUNCTION
Air Data Computer	Altitude Rate
Air Data Computer	Aircraft Altitude
Air Data Computer	Barometric Adjust
Radar Altimeter	Terrain Altitude
Central Computer	Command Altitude

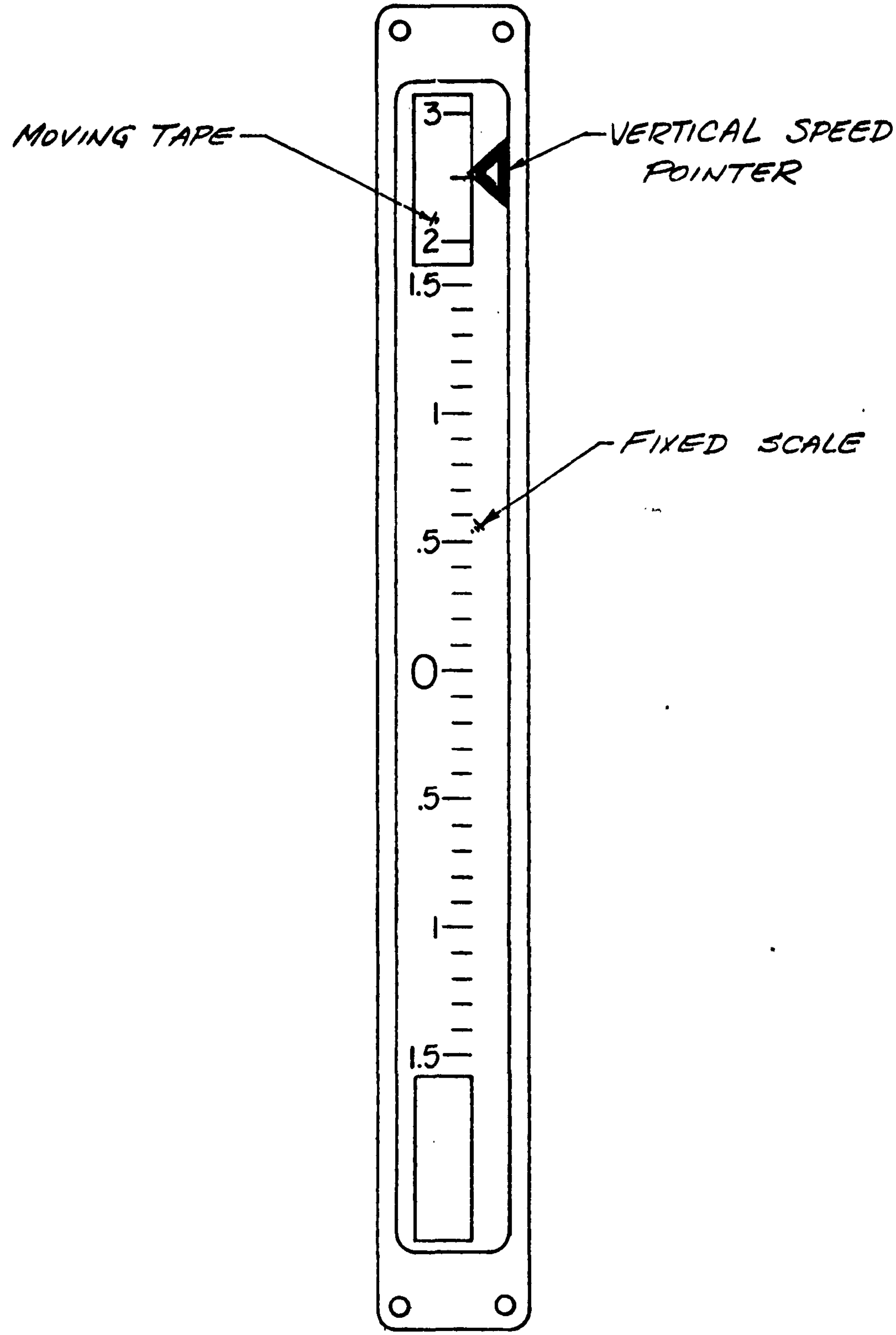
OUTPUTS

TO	FUNCTION
Display Generator	Ground Texture
Central Computer	Preselect Altitude
Terrain Mode Relay	Open-Close Circuit
Terrain Clearance Radar System	Terrain Follow
Air Data Computer	Barometric Adjust

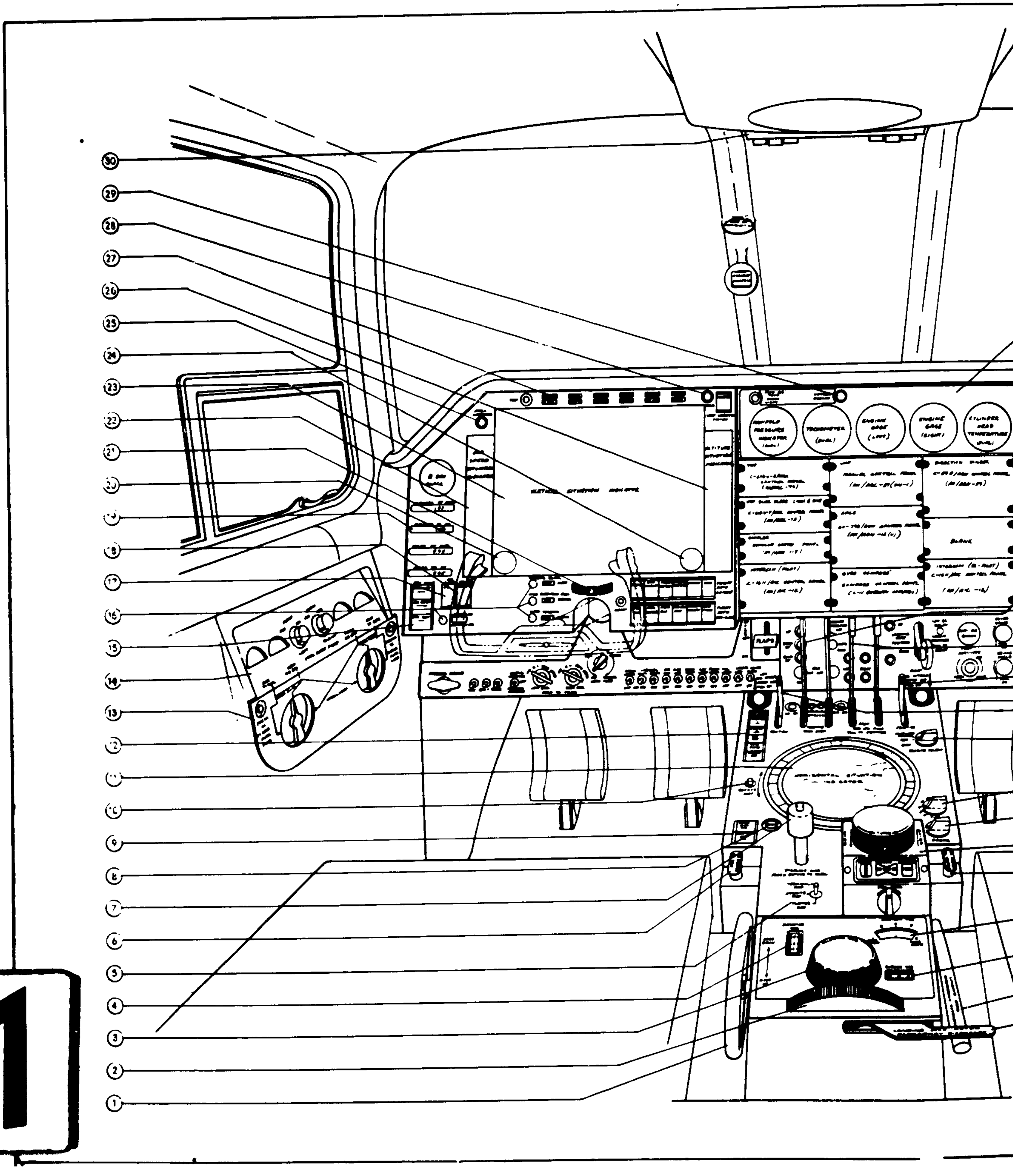
Exhibit 11 is a detail specification for the altitude indicator.

4.1.2.7 Caution Display System

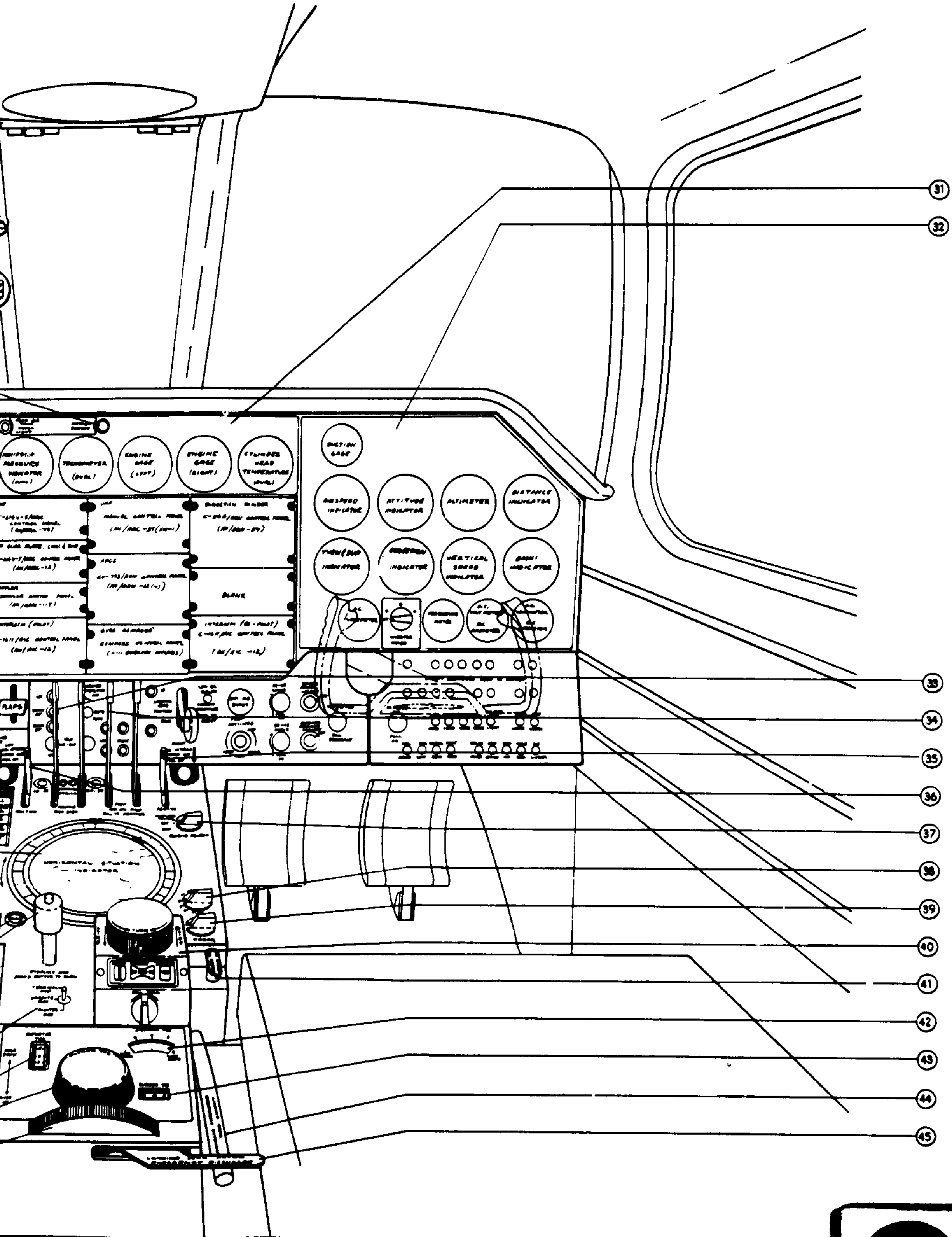
A panel of indicator lights to inform the pilot of dangerous or potentially dangerous conditions is provided. This panel is located immediately above the vertical situation display and below the glare shield where it commands the pilot's attention as he scans from the display to the outside world. See Figure 6 and Exhibits 12 and 13. The panel is composed of



VERTICAL SPEED INDICATOR
FIGURE 5

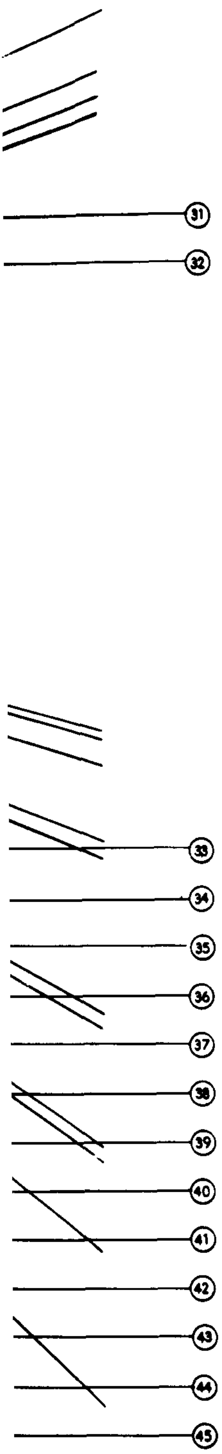

30
29
28
27
26
25
24
23
17
16
15
14
13
9
8
7
6
5
4
3
2
1
MANIFOLD PRESSURE INDICATOR (DUAL)
TACHOMETER (DUAL)
ENGINE GAGE (LEFT)
ENGINE GAGE (RIGHT)
CYLINDER HEAD TEMPERATURE (DUAL)
BLANK
FLAPS

1



1. ELEVATOR TRIM CONTROL KNOB
2. RUDDER TRIM CONTROL KNOB
3. AILERON TRIM CONTROL KNOB
4. ELEVATOR TRIM INDICATOR
5. MAP SCALE SELECT SWITCH
6. L.H. ENGINE OIL SHUTOFF
7. MAP SLEW CONTROL
8. HORIZONTAL DISPLAY CONTRAST AND
9. MAP MODE SELECT
10. MAP ORIENTATION SWITCH
11. HORIZONTAL SITUATION DISPLAY
12. COURSE ACQUISITION CONTROL SWITCH
13. FUEL CONTROL PANEL
14. FUEL QUANTITY INDICATING PANEL
15. NAV MODE SELECT SWITCHES
16. MAN INPUTS : MAGNETIC VARIATIONS,
17. "ADE" MASTER POWER SWITCH
18. RADAR "REMOTE" SWITCH
19. TIME & DISTANCE READOUTS
20. HORIZON SHIFT CONTROL
21. SLIP INDICATOR
22. AIRSPEED SITUATION DISPLAY
23. VERTICAL SITUATION DISPLAY
24. VERTICAL DISPLAY CONTRAST
25. STALL WARNING LIGHT
26. ALTITUDE SITUATION DISPLAY
27. "CAUTION" PANEL
28. VOICE WARNING SYSTEMS CONTROLS
29. MARKER BEACON LIGHT
30. LIGHTING CONTROL PANEL
31. ENGINE INSTRUMENT PANEL
32. CO-PILOT'S INSTRUMENT PANEL
33. THROTTLE LEVERS
34. PROPELLER PITCH CONTROL LEVERS
35. THROTTLE FRICTION CONTROL
36. PROPELLER PITCH FRICTION LEVER
37. BEARING SELECT SWITCH
38. TERRAIN AVOIDANCE RADAR
39. RADAR SELECT SWITCH
40. AUTOMATIC FLIGHT CONTROL SYSTEM
41. R.H. ENGINE OIL SHUT OFF
42. AILERON TRIM INDICATOR
43. RUDDER TRIM INDICATOR
44. EMERGENCY LANDING GEAR
45. EMERGENCY LANDING GEAR

2



1. ELEVATOR TRIM CONTROL KNOB
2. RUDDER TRIM CONTROL KNOB
3. AILERON TRIM CONTROL KNOB
4. ELEVATOR TRIM INDICATOR
5. MAP SCALE SELECT SWITCH
6. L.H. ENGINE OIL SHUTOFF
7. MAP SLEW CONTROL
8. HORIZONTAL DISPLAY CONTRAST AND BRIGHTNESS CONTROLS
9. MAP MODE SELECT
10. MAP ORIENTATION SWITCH
11. HORIZONTAL SITUATION DISPLAY
12. COURSE ACQUISITION CONTROL SWITCHES
13. FUEL CONTROL PANEL
14. FUEL QUANTITY INDICATING PANEL
15. NAV MODE SELECT SWITCHES
16. MAN. INPUTS: MAGNETIC VARIATIONS, TERRAIN ELEVATION, WIND DIRECTION & WIND VELOCITY
17. "AIDS" MASTER POWER SWITCH
18. "RADAR OPERATE" SWITCH
19. TIME & DISTANCE READOUTS
20. HORIZON SHIFT CONTROL
21. SLIP INDICATOR
22. AIRSPEED SITUATION DISPLAY
23. VERTICAL SITUATION DISPLAY
24. VERTICAL DISPLAY CONTRAST
25. STALL WARNING LIGHT
26. ALTITUDE SITUATION DISPLAY
27. "CAUTION" PANEL
28. VOICE WARNING SYSTEMS CONTROLS
29. MARKER BEACON LIGHT
30. LIGHTING CONTROL PANEL
31. ENGINE INSTRUMENT PANEL
32. CO-PILOT'S INSTRUMENT PANEL
33. THROTTLE LEVERS
34. PROPELLER PITCH CONTROL LEVERS
35. THROTTLE FRICTION CONTROL
36. PROPELLER PITCH FRICTION LEVER
37. BEARING SELECT SWITCH
38. TERRAIN AVOIDANCE RADAR ANTENNA TILT CONTROL
39. RADAR SELECT SWITCH
40. AUTOMATIC FLIGHT CONTROL SYSTEM CONTROLLER
41. R.H. ENGINE OIL SHUTOFF
42. AILERON TRIM INDICATOR
43. RUDDER TRIM INDICATOR
44. EMERGENCY LANDING GEAR EXTENSION HAND PUMP
45. EMERGENCY LANDING GEAR OVERRIDE LEVER

3

FIGURE 6

standard indicator assemblies available commercially. The lights are activated, in parallel with the voice warning system, by an electric signal from a sensor in the system, involved. Warning (Red) and Caution (Amber) indicators are provided, as follows:

Warning Indicators (Red): These indicate the existance of a hazardous condition requiring immediate corrective action.

Obstacle - Indicates that immediate evasive action must be initiated to avoid an obstacle in the flight path ahead.

TCRS Fail - Indicates that the Terrain Clearance Radar System is not functioning properly and that information on obstacles is no longer being provided.

CMTR Fail - Indicates that the computer is not functioning properly and that information being provided to the pilot in the form of command flight path, etc., is erroneous.

Wheels Up (J-50) - Indicates that a landing is being initiated with the landing gear retracted.

Autorotation (HU-1A) - Indicates that the rotor/engine gear and rotor/engine RPM ratio are out of phase.

Caution Indicators (Amber): These indicate the existance of an abnormal condition that is not, in itself, immediately hazardous. The indication permits the pilot to take corrective action where possible.

Gen Fail - Indicates a generator failure.

Invtr Fail - Indicates failure of the primary inverter.

Doppl Mem - Indicates that the doppler is in the memory mode.

Fuel Low - Indicates that fuel quantity is below a safe reserve.

Oxy Low - Indicates that oxygen quantity is below a safe reserve.

Air Data Unreliable (HU-IA) - Below 25 knots indicated airspeed, the pitot static system is unreliable.

The HU-IA installation will incorporate the following existing console caution indicators above the vertical situation display. See Exhibit 14.

Engine Oil	Transmission Oil Press
Engine Icing	Transmission Oil Hot
Engine Ice Detector Disarmed	Hyd. Press

Fuel Pressure Low External Power

Aux Fuel Low

Test Circuit: A "Test" button to check the circuit and bulbs of the caution panel and the stall warning light is located to the left of the caution panel just below the glare shield.

4.1.2.8 Voice Information Priority System (VIPS)

The voice information priority system provides for warning pilot and crew of dangerous and potentially dangerous conditions affecting flight. This is accomplished by transmitting a prerecorded voice warning message over the headset to forcefully direct the attention to the precise hazard and the remedial action to be taken.

The voice warning system provides for twenty prerecorded, selectivity worded warning messages of fifteen second duration each. The system has a priority selection which provides for multiple warning signals.

If a higher priority warning occurs when a lower priority message is being transmitted, the high priority warning immediately interrupts the message in play. All messages start with the first word of the message.

These warning messages will repeat until the fault is corrected or the channel silenced by the pilot. The system is operated in parallel with the warning lights which indicates the same fault.

The voice warning system (VIPS) has three main components. These components are: The Voice Warning Signal Unit, the Signal Summing and Override Assembly, the Pilot's Override Switch Assembly. The system is powered by twenty-eight volts, direct-current.

Exhibit 15 is a detail discussion of the Voice System.

This unit is an off-the-shelf item by Nortronics.

4.1.2.9 Central Display Computer

Data processing and computations required for the display system are performed by means of a Central Digital Computer. The computer accepts inputs from the sensor equipment and provides outputs to the display equipment as determined by the pilot controls. The computer functions include:

1. Vertical Display Symbol Displacement Commands.
2. Horizontal Display Symbol Displacement Commands.
3. Navigation Computations.
4. Cruise Control Computations.
5. Auxiliary Display Commands.

The computer is a combined incremental (DDA) and whole number, general purpose computer designed to solve real-time problems associated with the navigation of airborne vehicles. It is a serial digital computer utilizing a drum memory, modular construction, and silicon semi-conductor circuitry. The word length of both instruction and data words is 24 BITS plus a space

BIT; the machine has a total capacity of about 100,000 BITS The computer operates through several types of input-output conversion devices which are serviced by the computer.

The nature of the machine makes it extremely useful for certain types of data processing in which smoothing of data for displays is required. The entire computer, including the DDA section, is a stored program machine. Program changes may be effected by reading the new program into the memory by means of a tape. No rewiring is required. This feature provides extreme flexibility in adapting the computer to perform successfully in a wide range of airborne vehicles. The computer is designed to accept and deliver information at data rates required on high performance aircraft in order to take advantage of this flexibility. The computer includes all of the input-output conversion equipment, self checking circuitry and power regulation equipment.

4.1.2.9.1 Computer Functions

4.1.2.9.1.1 J-50 System

The central digital computer will perform the functions described in the following paragraphs. Detailed descriptions of the operations and computations performed by the computer as well as interface requirements are presented in Exhibit 16.

1. Navigation:

   The computer is capable of computing present position in any of three modes of navigation.

   a. Doppler - The computer accepts north and east velocity inputs from the doppler radar, compass heading, and true airspeed; it computes drift angle, wind, ground speed and present position in latitude and longitude.

   b. Air Data - (Wind Memory) The computer accepts true airspeed, compass heading, and uses doppler remembered wind to compute drift angle, ground speed and present position in latitude and longitude.

      --(Manual Wind) The computer performs the same functions as above except manual wind inputs are used instead of wind memory.

   c. OMNI-DME - The computer receives VOR - magnetic bearing from the OMNI receiver, magnetic heading, distance to OMNI-DME station from DME, and true airspeed; it computes drift angle, ground speed and present position in latitude and longitude. Navigation data is read into the computer from the map display where the desired positions are located with the acquisition symbol.

2. Map Transformation:

   A Lambert Conformal Projection is used for the horizontal map display, the coordinates of which are designated X, Y. Conversion from latitude, longitude to X, Y coordinates is performed by the computer as well as conversion from X, Y coordinates to latitude, longitude. As a result of the programming flexibility of the central digital computer, other map projections may be utilized. It is a relatively simple procedure to change the computer program to perform the proper map transformation for any desired map projection.

3. Command Path Orientation :

The computer controls the orientation of the command flight path as determined by the selection of switches labeled, "Flight Path Course",

The position and direction of the flight path on the vertical display corresponds to the position and direction of the course line on the horizontal display. The course line is determined in one of two ways.

a. The computer receives base and destination X, Y, coordinates of the course line from the map scanner and computes the course line map angle.

b. The computer receives course line base in X, Y coordinates from the map scanner and computes course line map angle from relative bearing information, compass heading, and map convergence angle.

4. Flight Path Pitch and Altitude Command:

Pitch and altitude of the flight path are controlled by the computer as determined by the selection of switches labeled "Flight Path Altitude".

Pitch of the flight path is determined in one of three ways:

a. Command pitch rate received from the terrain clearance radar system is integrated and used to command the pitch of the flight path.

b. The computer determines the proper path pitch angle which will produce a preselected rate of climb.

c. Command pitch is set to zero.

Altitude of the flight path is determined in one of two ways:

a. Command altitude of the flight path is computed as a function of flight path pitch command and aircraft velocity (ground speed).

b. Present altitude or preselected altitude is stored and becomes command altitude upon selection of the proper mode buttons.

5. Command Speed:

For maximum range or maximum endurance the computer computes command true airspeed from the cruise performance equations of the aircraft.

6. Landing:

The computer accepts field altitude, and glideslope and localizer deviation signals from the ILS system and operates on them to provide command path altitude, pitch and position to bring the aircraft safely down to FAA minimums.

7. Fuel Management:
From initial fuel quantity, fuel consumption rate, and ground speed, the computer determines fuel range remaining and fuel time remaining.

8. Display Computations:
The computer performs the computations necessary to position the symbols on the primary displays as well as auxiliary indicators.

   a. Map Drive - The x, y position outputs from the computer are compared with the position x, y feedback signals from the map scanner, and the error is used to drive the map in x, and y.
   b. Computed Course - The course line angle is computed in terms of relative bearing and displayed on the horizontal compass ring.
   c. Course Line Position - The position of the course line on the horizontal display is computed in terms of x, y distances from the display center.
   d. Aircraft Symbol Position - The computer continuously computes the position of the A/C symbol on the horizontal display in terms of x, y coordinates. This is accomplished for both fixed map operation and moving map operation. The computer also commands the displacement of

of the A/C symbol from the display center by an amount determined by the offset control input.

e. Vertical Display Flight Path Position - The vertical display flight path position is determined by differencing the command path orientation with the aircraft orientation to give the display command heading, altitude, pitch, and displacement. In addition, these parameters are transformed to provide the correct display perspective.

f. Airspeed Marker - The computer commands the airspeed marker movement on the vertical display by differencing the command airspeed with present airspeed.

g. Range Circle - From the fuel range computation the computer positions a fuel range circle on the horizontal display. Fuel range and fuel time remaining are also displayed on digital counters.

h. Range and Time to Destination - The computer determines range and time to destination by using x, y coordinates of present position, x, y coordinates of destination, and ground speed. Range and time to destination are displayed on digital counters.

i. Impact Point - The computer positions the impact point on the vertical display from inputs of angle of attack and drift angle.

4.1.2.9.1.2 **HU-1A System**

As presently configured, the computer will perform basically the same computations for both the J-50 and HU-1a versions of the display systems, since the two systems require the same display symbology and auxiliary information with a few exceptions.

Additional computations which will be performed for the HU-1A version are as follows:

1. Autorotation:

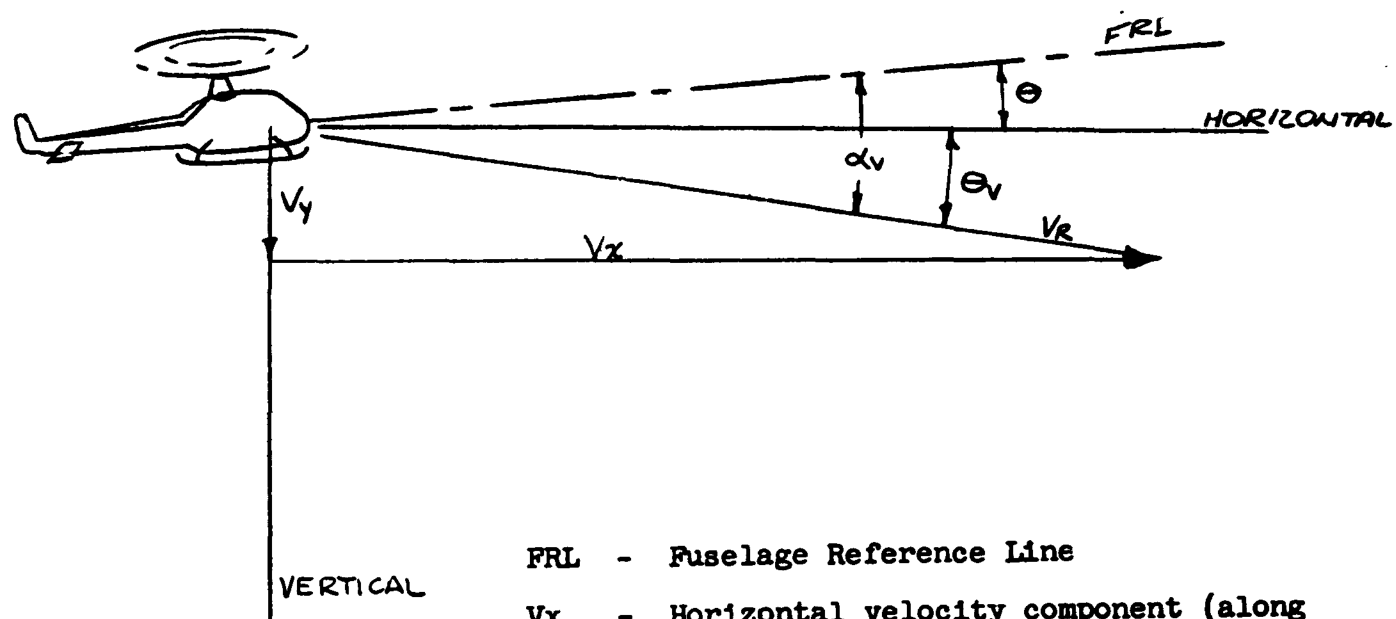
   The computer accepts inputs of engine RPM and rotor RPM and senses when the helicopter enters autorotation. In autorotation a warning light goes on, and the fuel range circle on the horizontal display becomes an autorotation range circle. This circle indicates the safe range within which the helicopter may descend under autorotation conditions.

2. Vertical Angle:

   Vertical angle is computed from doppler vertical velocity doppler heading velocity, and pitch angle. Refer to Figure 7. Vertical angle is used in the HU-1A system where angle of attack is used in the J-50 system. If the doppler signals are not being received, the impact point will not be displayed.

3. RAILS:

   The computer will be capable of operating on signals from the RAILS system and providing commands for the flight path on the vertical display.



FRL	-	Fuselage Reference Line
Vx	-	Horizontal velocity component (along heading component of groundspeed)
Vz	-	Vertical velocity component with respect to earth.
V_R	-	Resultant velocity
Θ_V	-	Angle between resultant velocity vector and horizon.
Θ	-	Pitch angle
α_V	-	Vertical angle

$$\alpha_V = \Theta - \Theta_V$$

Figure 7. Vertical Angle

Other computations which can be performed by the computer for the HU-IA are limited in the present system due to inadequate sensors. An example of this is the safe flight envelope computation. This computation would provide a prediction to avoid excessive load factor maneuvers, lack of control, and rotor instability. Airspeed sensors necessary for this computation are not presently available.

4.1.2.10 Terrain Clearance Radar System (TCRS)

The TCRS supplies terrain information required for terrain following, terrain avoidance, ground mapping, and obstacle warning. It is based on the principle of Texas Instruments' Terrain Clearance Radar which is currently in use in Army drones.

For terrain following the radar scans vertically through the flight path of the aircraft as shown in Figure 8. The scan is ground path stabilized by inputs from the doppler radar.

A pre-programmed negative "g" template is compared with a positive "g" input created by the radar from the amount of video returned in the envelope of the scan pattern. The resultant output is directly proportional to the "g's required to maintain a pre-set altitude

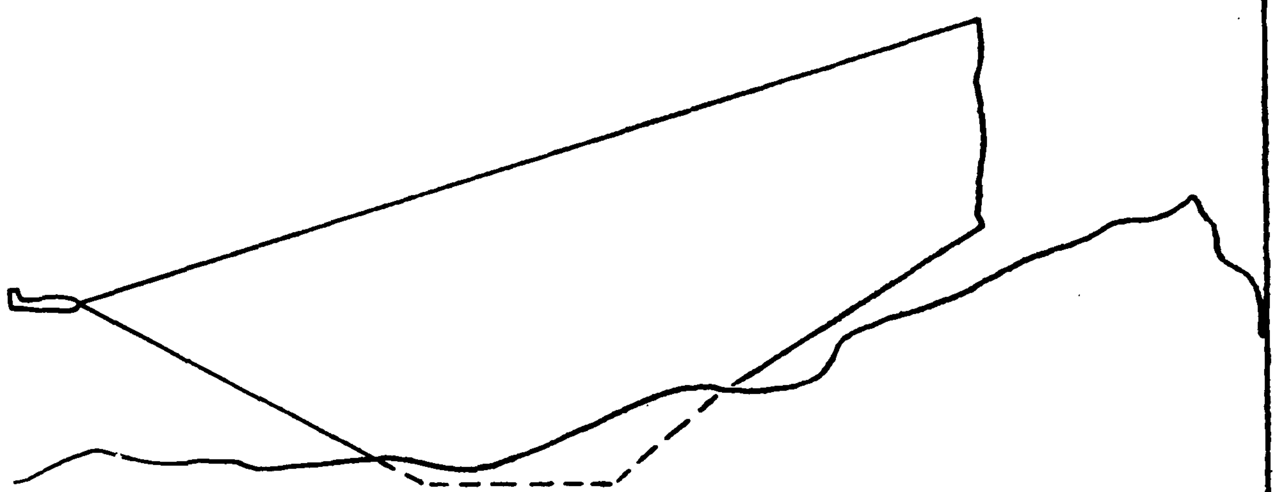


FIGURE 8. TERRAIN FOLLOWING TEMPLATE

above the terrain. Minimization of overshoot after clearing an obstacle is inherent with this principle since the output will be negative as well as positive.

The TCRS has the following components: Power Supply, Antenna/R. F. Assembly, Receiver, and Transmitter.

For terrain following, the TCRS sends vertical scan information, in the form of up-down commands, to the Central Computer for the generation of the flight path commands for the Vertical Display. The far end of the displayed flight path is positioned as a function of the radar up-down commands. The near end is positioned as a function of the aircraft altitude with respect to a computed flight path altitude (terrain clearance altitude).

Upon initial selection of the terrain following function, the flight path is displayed at a standard altitude position below the aircraft. Under normal operation, the TCRS computes commands which position the flight path. The pilot should respond to the flight path and maintain approximately the same altitude relationship to the path. If the pilot fails to respond to the flight path commands and flies the aircraft into an unsafe condition, the flight path pitches to maximum (climb - high), the radar sends a signal through the Voice Information Priority System (VIPS) commanding him to take corrective action. The same signal is also sent to the "obstacle" light on the pilot's instrument panel. During terrain following, if the TCRS fails, the VIPS commands corrective action, the "TCRS Fail" light on the pilot's instrument panel lights, and the flight path is pitched up to command aircraft maximum rate of climb (climb-high). Capability is provided for selecting the terrain following function over the range of 250 feet to 1000 feet or radar altitude.

When in the "Operate" condition, regardless of mode, the TCRS scans vertically and provides obstacle warning. It searches for obstacles in the path of the aircraft and provides obstacle warning signals to the central computer to command maximum aircraft climb on the displayed flight path, to VIPS for aural warning, and to the "obstacle" light on the instrument panel for visual warning.

For terrain avoidance, the TCRS sends Azimuth scan, clearance plane (profiloscope) type, information to the scan converter in the display generator. The scan converter converts the radar video from radar scan-rates to the television scan-rates required for presentation on the horizontal display. Terrain which exists on the aircraft flight plane will be displayed on the horizontal display.

For ground mapping, the radar sends ground mapping video to the scan converter for presentation on the horizontal display. This information is limited at high altitudes because the beam is not spoiled. However, at lower altitudes useful search information can be obtained. A tilt control is provided for vertical beam positioning.

Terrain avoidance or ground mapping information is overlaid on the horizontal display map as a ± 20 degree PPI display. The pilot can observe obstacles in front of his aircraft at, above, or below his flight vector and compare them with his map display.

For both terrain avoidance and ground mapping, the radar ranges are selected simultaneously with the selection of map scales. The displayed map area diameters are approximately 6, 24, and 96 miles.

The radar is mechanized such that terrain following may be selected with or without terrain avoidance or ground mapping. When one of the horizontal functions is selected with terrain following, the radar antenna scans twice in the vertical direction and once in the horizontal direction per second. This scan pattern supplies adequate information for both functions.

The radar is roll and drift angle stabilized during all functions, and is flight vector stabilized during terrain following. This is accomplished by feeding to the radar, roll angle information from the vertical gyro, drift angle from the central computer, angle of attack from the angle of attack sensor or the central computer.

For detailed information on the operation of the TCRS or on the mechanization of the functions of the Display System associated with the radar outputs, see Exhibit 17.

4.1.2.11 Angle of Attack Sensor

The J-50 Aircraft Angle of Attack Transducer provides a synchro output to the Terrain Clearance Radar System and a digital output to the Central Digital Computer. The Transducer will be installed in a probe on the wing outboard of the engine nacelle. The location of the propellers prevents installation of the transducer on the fuselage. For the HU-1A installation, the computer will determine the vertical angle velocity vector from Doppler inputs of vertical and horizontal speed.

The detail specification for the Angle of Attack Sensor is included in Exhibit 18.

4.1.2.12 Fuel Monitoring System

The Fuel Flow Transmitter is a volumetric type with flow range of 60-400 PPH. The installation provides an AC output of fuel flow to the Central Digital Computer.

Exhibit 19 is a detail specification for the Fuel Flow Transmitter.

4.1.2.13 Air Data System

The Air Data Computer utilizes inputs of static pressure, total pressure, total temperature and barometric correction to compute true air speed and pressure altitude. The true airspeed output is digital for the Central Digital computer and analog for the True Airspeed Indicator. The altitude output is digital for the Central Digital computer and analog for the Altitude Indicator. See figure 9.

The Air Data System is unreliable below 25 knots IAS. The unreliable condition output signal is provided for the caution panel, VIPS and display generator.

A detail specification for the Air Data Computer is included in Exhibit 20.

4.1.2.14 860E-1 D.M.E. System

The 860E-1 Distance Measuring equipment measures the time required for the propogation of an interrogation pulse to the select TACAN or VORTAC ground facility and the transmission of a reply pulse back to the aircraft. The time is converted to a range output signal which is furnished to the range indicator and to the digital computer.

The 860E-1 is off the shelf equipment and does not require a detailed purchase specification. Requirements are listed in Exhibit 29.

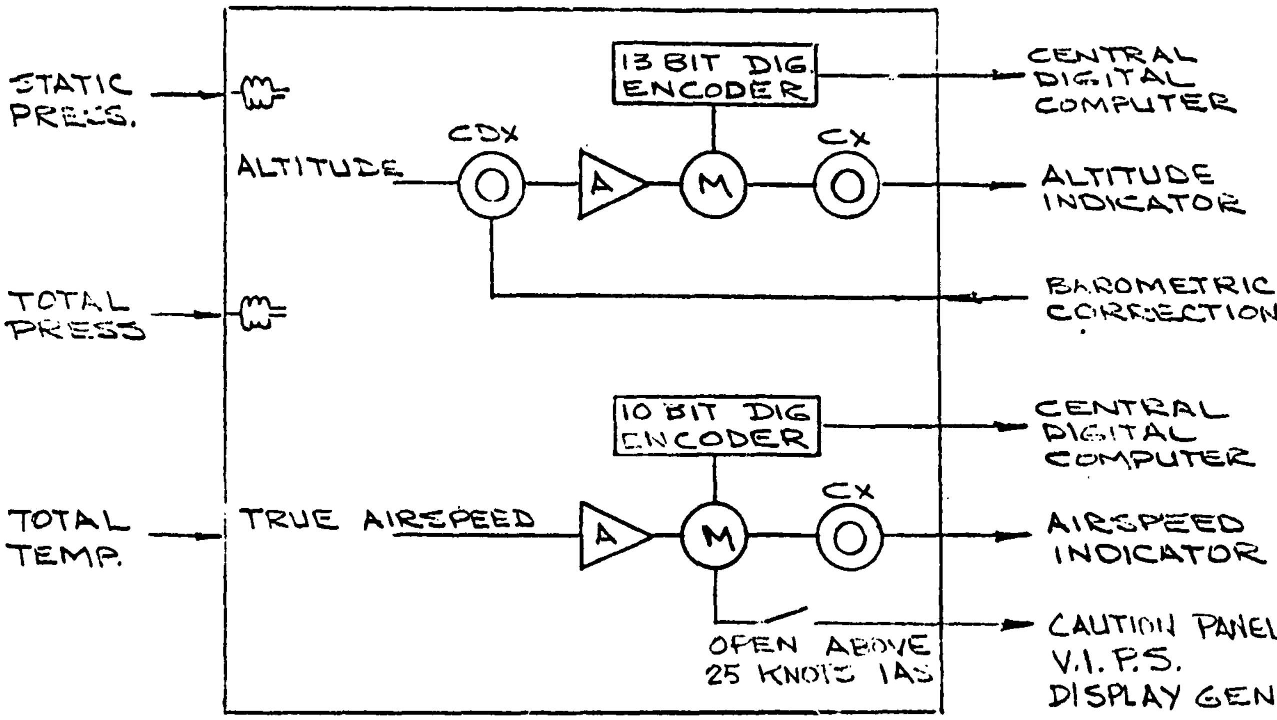


Figure 9. Air Data System Schematic

4.1.2.15 OMNI Converter

The Navigation Radio Output Signals from the AN/ARC-73 (Collins 51X-2B Receiver) are applied to the 344B-1 Instrumentation unit. The signals are converted in the instrumentation unit to provide the following outputs.

a. VOR relative bearing signal to the C-6 compass indicator and to the Horizontal Display bearing cursor.

b. VOR/LOC Course Deviation Signal to the Course Selector indicator.

c. VOR Course Deviation Signal to the Automatic Flight Control System.

d. LOC Course Deviation Signal to the Digital Computer.

This unit is off the shelf equipment and does not require a detailed purchase specification. Requirements are listed in Exhibit 29.

4.1.2.16 C-11 Gyrosyn Compass System "Power Supply"

The power supply for the C-11 Compass system is a Sperry Gyroscope Company Part Number 1775143, which is a plug-in component mounted in the C-11 Compass rack assembly. The power supply furnishes regulated d-c voltage to engergize the latitude control circuit in the directional gyro and the controller.

Power required from the aircraft is nominal 115 volts, 400 cps single-phase. The use of full-wave bridge rectifier provides filtered 305 volt d-c supply to a voltage regulator for use in latitude control circuitry.

This unit is an "off the shelf" item for which a purchase specification is not required.

4.1.2.17 D.C. Generators

4.1.2.17.1 J-50 Installation: The Engine-driven 100 ampere, 28 V d-c generators, that power the electrical system in the Beechcraft J-50 airplane, are replaced with 300 ampere generators, Bendix Aviation Corp. Part Number 30E20-11, to supply the added display system loads. The batteries, generator voltage regulators, and generator relays that are furnished with the J-50 airplane, are retained without change.

4.1.2.17.2 HU-1A Installation: The transmission driven 300 ampere, 28 V d-c Main Generator that supplies power for the Helicopter electrical system will be replaced with a 400 ampere Unit (Jack & Heintz Modified type 30010 Generator) to supply the added display system loads. The voltage regulator and overvoltage relay that is used with the 300 ampere generator will be retained for use with the 400 ampere generator.

An Engine driven 100 ampere, 28 V d-c standby generator and controls and the 24 volt battery that are furnished with the HU-1A will be retained without change.

4.1.2.18 Inverters

4.1.2.18.1 J-50 Installation: Since alternating current power is not provided in the Beechcraft J-50 airplane, a main and an emergency 115 Volt, 400 cps inverter have been added. The 3000 VA main inverter, Bendix Part No. 32E03-9 supplies a-c power to the display system and radio loads. The 500 VA emergency inverter, Bendix Part Number 32E01, supplies a-c power to the navigation radio and instruments upon failure of the main inverter.

4.1.2.18.2 HU-1A Installation: Two AN3532-2 250 VA inverters are supplied with the HU-1A Helicopter. The increase in a-c load due to the display system installation necessitates replacing one of the inverters with a 3000 VA unit. This 3000 VA main inverter, Bendix Part Number 32E03-9, will supply power to the HU-1A existing a-c loads and added AAAIS loads. The remaining AN3532-2 inverter will normally be inoperative. This 250 VA spare inverter will supply a-c power to the HU-1A existing loads upon failure of the main inverter.

4.1.2.19 V.H.F. Nav/comm Receiver (HU-1A installation only)

The primary function of the Collins 51X-2B Receiver, is to receive, amplify, and detect VOR/LOC Navigation Radio Signals. The output of the receiver is applied to the 344B-1 instrumentation unit for conversion to VOR Bearing and VOR/LOC Course Deviation Signals. The receiver is also used for reception of V.H.F. communications. An aural navigation signal output and communication radio output are connected to the headset by means of the interphone control.

4.1.2.20 Magnetic Variation Compensation

The magnetic variation compensator is located on the display system panel and provides for manual insertion of magnetic variation. The compensator receives magnetic heading from the C-11 compass system and modifies it, as a function of the variation setting, to provide true heading information to the display system and APN-118 Doppler.

The compensator is positioned through a differential synchro by a manual set knob, geared to a numerical counter for visual readout. The compensator is capable of correcting for ± 180 degress of magnetic variation.

4.2 ADDITIONAL EQUIPMENT PROVISIONS

Space, cooling and power provisions for additional equipment are available. If additional equipment is installed, however, its weight must be compensated for by the deletion of fuel.

4.2.1 AN/APX-44 IFF

It appears that installation of IFF equipment will be a requirement for all aircraft flying under IFR conditions. Space, weight and power provisions have been made so that the Army may install the AN/APX-44 equipment after receipt of the aircraft.

4.2.2 Safe Condition, Approach - Take Off (SCAT)

SCAT is a system which indicates to the pilot precise attitude and power requirements during low speed flying. The system consists of the following components:

* Lift Transducer - The source of information for the SCAT System is the Lift Transducer which is mounted on the underside of the wing leading edge. The Lift Transducer by means of a variable reluctance transformer transduces the position of the sensing vane, measuring coefficient of lift (C_L), to the SCAT Signal Summing Unit.

* Flap Transmitter - The effect of wing flap position on coefficient of lift (C_L) is introduced into the SCAT Signal Unit by the Flap Transmitter which is connected to the flaps through mechanical linkage.

* SCAT Signal Summing Unit - The coefficient of lift signal with flap position compensation is combined with a gyro-oriented horizontal accelerometer signal within the SCAT Signal Summing Unit. The resultant integrated change of acceleration and lift ratio (C_L/C_L max) signal is supplied to the SCAT Indicator and/or Automatic Flight Control System and/or the Computer.

* SCAT Indicator - The instantaneous speed condition information utilized by the pilot is continually displayed by a pointer moving across a special scale on the SCAT Indicator. When the pointer is centered the aircraft is flying at the optimum lift condition.

Space and power provisions have been made so that the Army may install SCAT after receipt of the aircraft. The SCAT indicator may be used, or the flight path on the vertical display may command the proper action. The computer will accept the SCAT input and command the speed market ribbon for this display. The principles of operation of the SCAT system do not permit its use on the helicopter.

4.2.3 Automatic Terrain Following Study

Under the present contract with the Army, there is no requirement to couple the Terrain Clearance Radar System to the AN/ASW-12 Automatic Flight Control System for automatic terrain following. However, a Douglas funded study has been conducted on the J-50 in conjunction with other aircraft to evaluate the requirements for the automatic tie-in. Preliminary results indicate the need of a coupler between the two systems for modulating, shaping, and limiting the command signal from the radar. Also there is a requirement for a computer study to determine gains for stability and to verify the hardware required. A detailed summary of the study is included in Exhibit 3.

Although the physical tie-in of the radar to the AFCS in the J-50 or HU-1A is not required as part of the current effort, Douglas is planning to continue the computer studies for the J-50 tie-in as a part of a study on a group of airplanes. This information will be forwarded to the Army in event there is a desire to couple the automatic terrain following during the Army evaluation phase of the program.

4.2.4 Forward and/or Down Looking Televisions and Infra-Red

Demonstration of the applicability of this system to ASR-2 and ASR-3 aircraft is possible since the system is limited only by the sensors. Should a requirement arise for forward and/or down looking television or infra-red displays, the display system can process and display this information on either the vertical or horizontal cathode ray tubes.

4.2.5 Standby Attitude Indicator

Space is available in the pilot's instrument panel for the installation of a standby attitude indicator.

4.3 SYSTEM INTERCONNECTION

The integrated aircraft cockpit display system consists of the central digital computer, display generator, vertical display, horizontal display, auxiliary displays, and the various associated sensory units.

4.3.1 Block Diagram

The grouping of equipment into computer, displays and sensors is illustrated in the simplified block diagram of figure 2. More sophisticated sensors may be substituted in this system without affecting the installation or the functions of the computer or displays. The computer will, of course, be able to send more accurate information to the displays if more accurate information is available from the sensors.

Detail schematics of the system installations are shown in Exhibits 21 and 22.

4.3.2 Signal Characteristics

Exhibit 23 is a compilation of signals for the display system in which each signal is described in as much detail as is available at this time. Figure 10 is an example of signal description. The assigned signal number is cross-referenced on the schematic diagrams of Exhibit 21 and 22. These three exhibits form the focal point of the design effort for the display system. They are the gathering and comparison point for all equipment

DOUGLAS AIRCRAFT COMPANY, INC. EL SEGUNDO DIVISION EL SEGUNDO, CALIFORNIA

SYSTEM INTERFACE SPECIFICATION

SIGNAL NAME ____________________ SYMBOL __________ NO. ________

RANGES	MAX	MIN
Physical Range		
Conversion Device Physical Rge.		
Conversion Device Digital Rge.		
Conversion Device Voltage Rge.		

ZERO SETTING ____________________

ANALOG SCALE FACTOR __________ DIGITAL SCALE FACTOR __________

DIGITAL CONVERSION ____________________

INPUT/OUTPUT IMPEDANCE ____________________

ACCURACY ____________________

MAX.RATE OF CHANGE ____________________

RESOLUTION ____________________

NULL ____________________

EXCITATION ____________________

SOURCE OF EXCITATION ____________________

PERIPHERAL EQPT. MFR. ____________________

UNIT NAME ____________________

PERIPHERAL DEVICE ____________________

ACCURACY ____________________

INPUT/OUTPUT IMPEDANCE ____________________

DISCRETE SIGNAL ____________________

METHOD OF SWITCHING: ______ TRANSISTOR ______ RELAY ______ SWITCH ______

EXCITATION ____________________

SOURCE OF EXCITATION ____________________

OPEN/CLOSED CIRCUIT MEANS ____________________

REMARKS:

FIGURE 10

signal compatability, they serve as a check list for individual engineers who are responsible for specific equipments, and they will form the basis of the overall wiring schematic of the aircraft.

It should be noted that one form being used in Exhibit 23 is tailored for digital computer interface information, and can be used directly by the programmer in programming the computer. Another form is used to describe signals, which are not related to the computer.

4.3.3 System Control Layout

Physical relationship of the system controls is shown in figure 6 and Exhibits 12 and 13 for the J-50 and in Exhibit 14 for the HU-1A. The arrangements are the result of detailed studies which combined human factors and the physical constraints of the aircraft through a time-line analysis of the proper sequence the pilot must go through in the use of the system.

A Time Line Analysis is a motion and time study of the required operations to perform a particular task graphically detailed on a time scale. The analysis is simply one of determining the motions required to perform the operation and then assigning predetermined time standards to each limiting motion. The Time Line Analysis determines the total time required to complete one or a series of operations the pilot must perform in flying the airplane.

When compared with the time available to perform the operations, it determines the location of equipment and the necessity for combination of tasks and/or integration of equipment. A detailed description may be found in WADC Technical Report 56-488 (AD-97305) Procedures For Including Human Engineering Factors in the Development of Weapon Systems By H. P. Vankott, and J. W. Altman, Oct. 1956. Examples of this analysis are given in Exhibit 24.

5.0 FACTUAL-DATA SYSTEM OPERATION

5.1 DISPLAY SYMBOL DESCRIPTION

In order to best describe the operation of the display system, a definition of symbols on the two primary displays is required. The two primary displays will consist of cathode ray tubes upon which are projected video displays to provide the pilot with command and actual flight information.

5.1.1 Vertical Display Symbol Description

Both fixed wing and helicopter versions of the vertical display will employ the same symbology with the possible addition of a landing point reference in the helicopter display. The vertical display is the primary source of information for azimuth, pitch, roll, velocity and altitude conditions and commands. These are described using the following symbols.

5.1.1.1 Contact Analog Terrain

The basic analog display is anchored to the real world in every respect so that the surface planes are perceived in 3-dimensional space, and all motion between the aircraft and these surfaces is same as aircraft motion. Perceived motion of the terrain texture provides the pilot with information about the direction of motion. The textured surface of the ground plane is discernible at all altitudes; the size and number of the texture elements is a function of the altitude up to saturation, thereafter maintaining the same relative size and number. The texture is made up of a grid pattern. The texture varies in size and appearance as a function of distance from the horizon.

A display of this type is shown as figure 11. The shape of the texture element is a function of the aircraft pitch attitude. It will appear in the true shape in a vertical dive and perspectively distorted in all other attitudes as a function of attitude. The textured ground surface provides the pilot with an analog of a surface that is much the same as that perceived through contact flight over a flat terrain. When the attitude is such that the horizon is visible, the texture moves downward on the vertical display scope as a function of the forward motion of the aircraft. The horizontal line moves up or down with a change in pitch angle and rotates about an axis normal to the display scope with a change in roll angle. A change in heading angle is indicated by lateral motion of the textured pattern.

5.1.1.2 Contact Analog Sky Texture

The sky plane is also represented by a textured surface of a considerably smaller number of elements than the earth texture and with the shape of stylized clouds, See Figure 11. The cloud pattern represents clouds located at an extremely high altitude and long range.

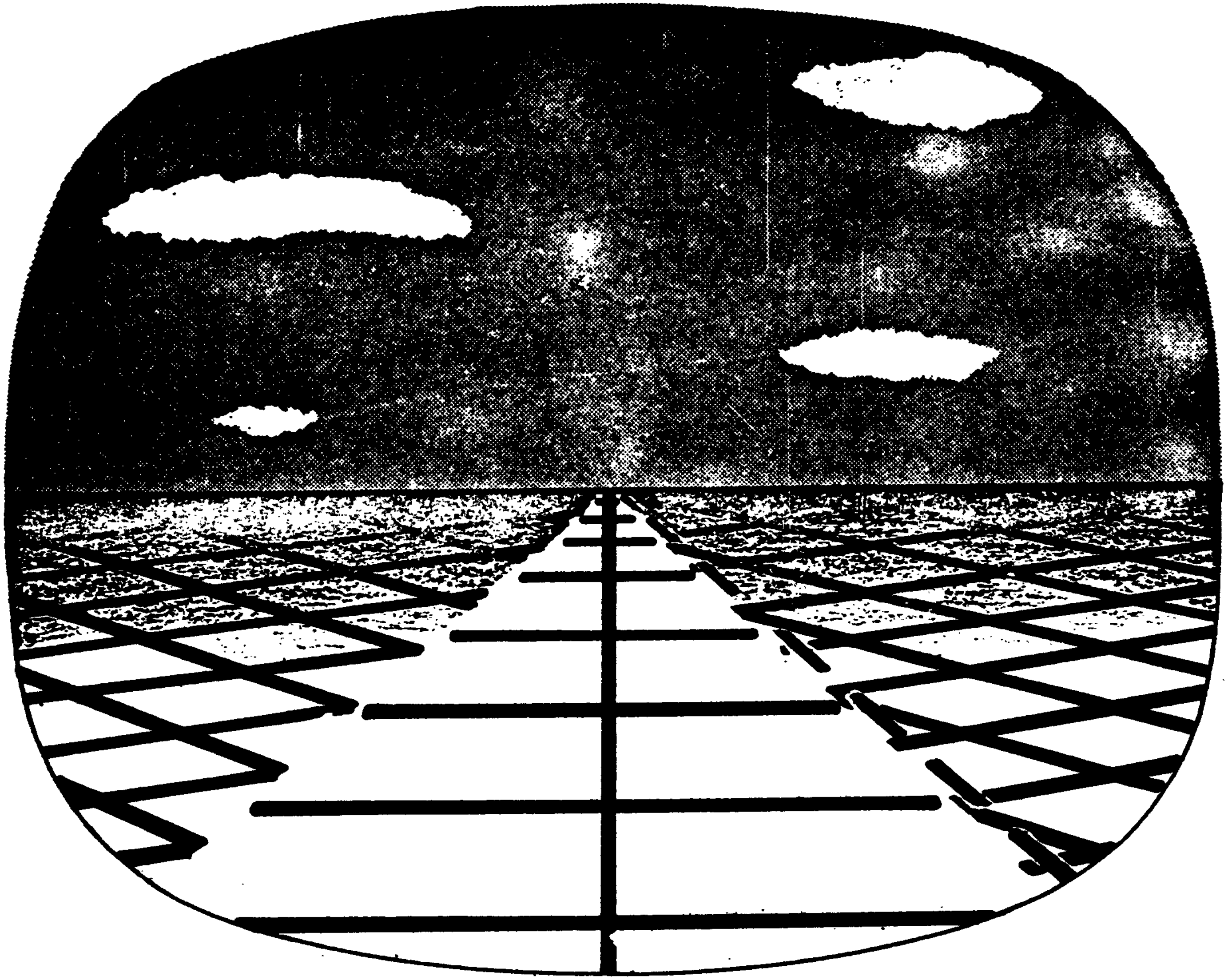


FIGURE 11
CONTACT ANALOG DISPLAY

5.1.1.3 **Pitch Angle Marks**

A series of small horizontal lines are presented at fixed angles to allow the pilot to reasonably determine his pitch attitude.

5.1.1.4 **Flight Path**

The vertical display will also contain a flight path. The earth coordinate position, attitude, altitude, and velocity of the path will be controlled by command signals received from the computer. Path elements, ("Tar Strips" similar to lines on a highway) will appear on the path way and move toward the observer in the same manner as the ground texture.

The size of the path (Apex angle), indicates the altitude the aircraft is above the commanded flight path. The lateral displacement of the near end of the flight path will indicate the amount that the aircraft is displaced from the path in position. The location of the apex point of the path relative to the horizon will indicate the pitch angle being commanded. The lateral displacement of the path apex point will indicate the difference between aircraft heading and command heading.

Figures 12 and 13 will aid in visualizing the relative size and shape of the flight path, as seen on the vertical display, as aircraft altitude above the path varies. Figure 12 shows the near end perspective width of the flight path in inches measured along the bottom edge of the display screen as a function of the normalized altitude above flight path. Figure 13 shows the flight path angular deviation from the horizontal as a function of normalized altitude above flight path. Both figures assume on course flight conditions with the aircraft pitch angle equal to the flight path pitch angle.

Index marks can be provided on the frame of the vertical display to indicate when the aircraft is above the flight path by an amount equal to some fraction of the flight path width. However, it is recommended that calibration marking be deferred until Army in-flight evaluation determines optimum path width and optimum distance above the path. These dimensions are adjustable by merely changing constants in the computer.

5.1.1.5 Speed Ribbon

A speed ribbon will be positioned along the right hand side of the flight path when desired. This ribbon indicates the difference between present aircraft speed and command aircraft speed such that if the aircraft is

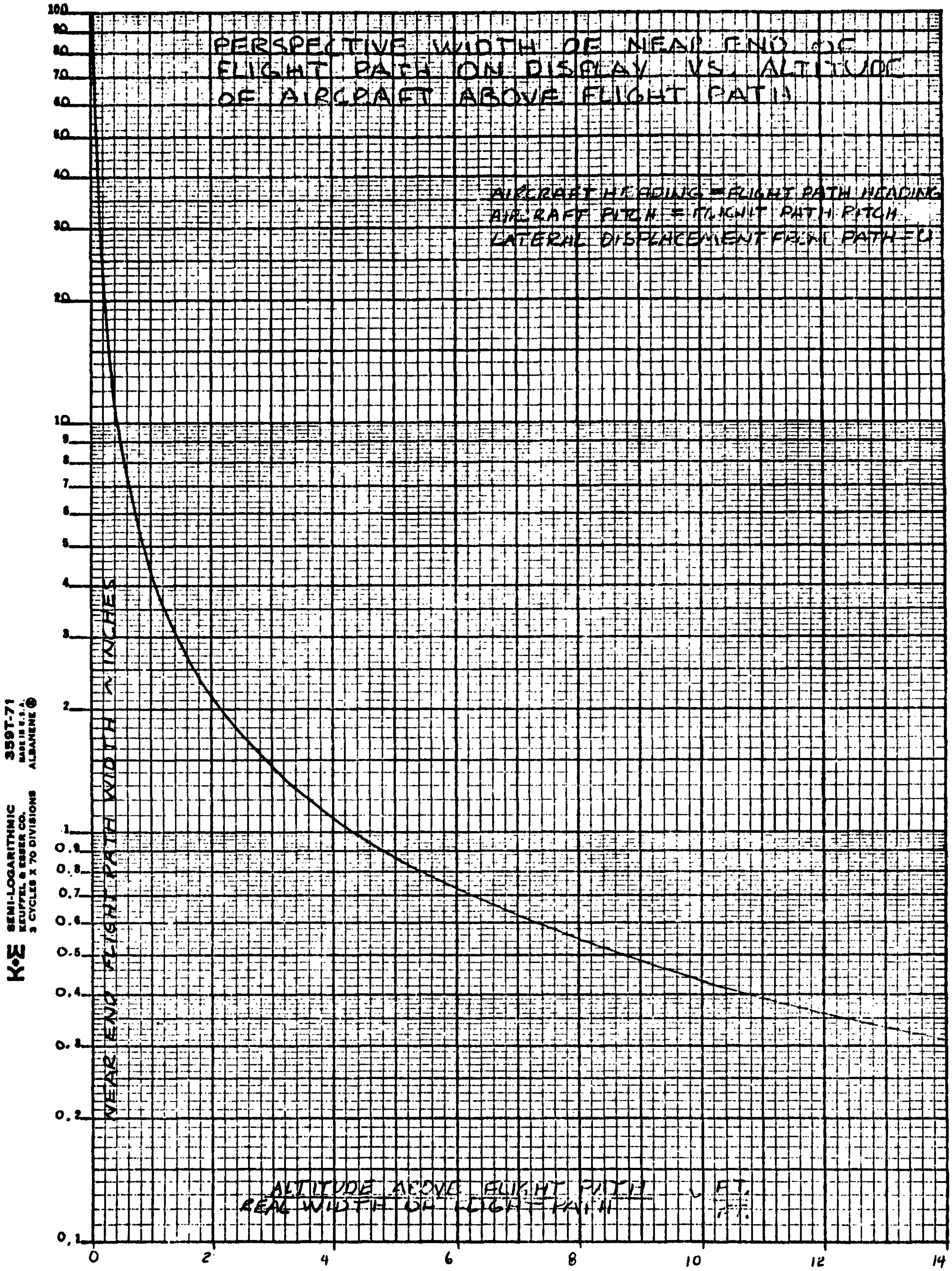

PERSPECTIVE WIDTH OF NEAR END OF
FLIGHT PATH ON DISPLAY VS. ALTITUDE
OF AIRCRAFT ABOVE FLIGHT PATH
AIRCRAFT HEADING = FLIGHT PATH HEADING
AIRCRAFT PITCH = FLIGHT PATH PITCH
LATERAL DISPLACEMENT FROM PATH = 0
NEAR END FLIGHT PATH WIDTH ~ INCHES
ALTITUDE ABOVE FLIGHT PATH ~ FT.
REAL WIDTH OF FLIGHT PATH ~ FT.
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
4
6
8
10
12
14
K•E SEMI-LOGARITHMIC
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS
359T-71
MADE IN U.S.A.
ALBANENE

FIGURE 12

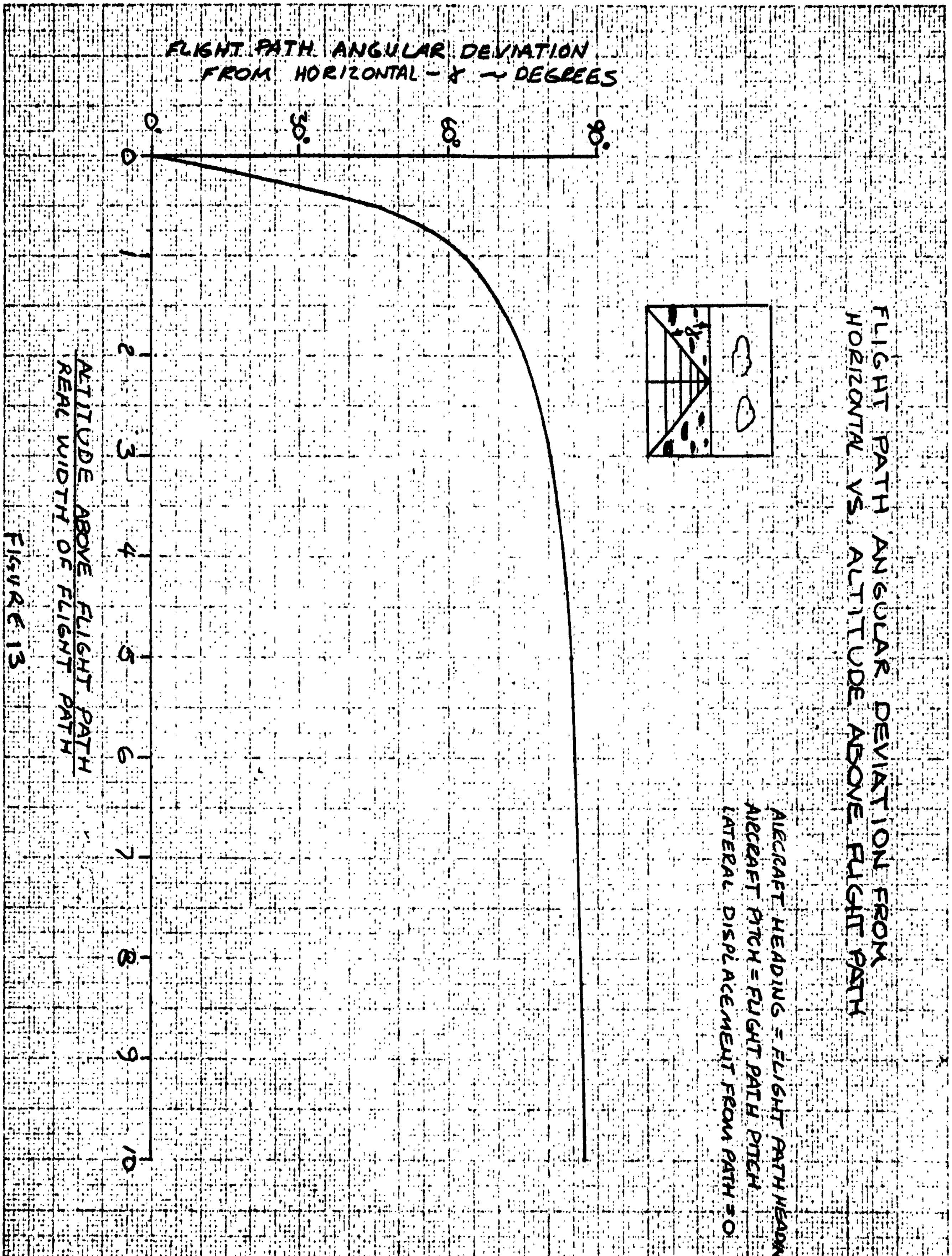

FLIGHT PATH ANGULAR DEVIATION
FROM HORIZONTAL – γ ~ DEGREES
0°
30°
60°
90°
0
1
2
3
4
5
6
7
8
9
10
ALTITUDE ABOVE FLIGHT PATH
REAL WIDTH OF FLIGHT PATH
FLIGHT PATH ANGULAR DEVIATION FROM
HORIZONTAL VS. ALTITUDE ABOVE FLIGHT PATH
AIRCRAFT HEADING = FLIGHT PATH HEADING
AIRCRAFT PITCH = FLIGHT PATH PITCH
LATERAL DISPLACEMENT FROM PATH = 0

FIGURE 13

flying too slow the ribbon will move toward the horizon and if the aircraft is moving too fast, the ribbon will move away from the horizon.

5.1.1.6 Pull Up Marker

A pull up marker will be available to indicate a pull up point to the pilot. This marker will be driven by the display computer and will appear as a heavy line on the flight path moving toward the observer as the pull up point is reached.

5.1.1.7 Impact Point

An impact point represented by a small square will be located with respect to display center (i.e., aircraft centerline) to indicate the angular position of the aircraft velocity vector. If there is no wind, and the impact point coincides with the far end of the flight path, the aircraft velocity vector is parallel to the command path. Deviation of the impact point to either side of the far end of the flight path is an indication of the difference between the aircraft velocity heading and the command path heading. Deviation of the impact point above or below the far end of the flight path is an indication of the difference between the aircraft velocity vector pitch angle and command path pitch angle.

Figures 14 a, b, c, and d will help to clarify the usage of the impact point on the vertical display. Figure 14 a indicates the velocity vector is level and on course. Figure 14 b shows the velocity vector pitched up with respect to the path but still on course heading - wise. Figure 14 c shows the aircraft displaced to the left of the command course, the velocity vector pitched up with respect to the horizon and pointing to the right of the command course. Figure 14 d shows a typical landing display; the velocity vector is pitched down at the same angle as the command path, and on course.

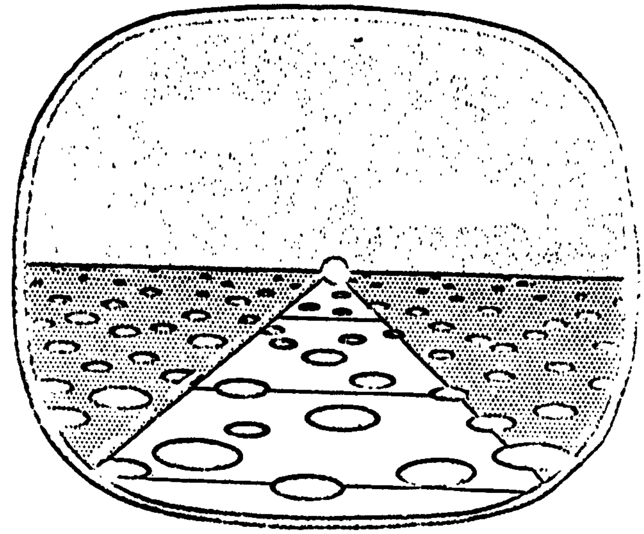


Figure 14a
Level - On Course

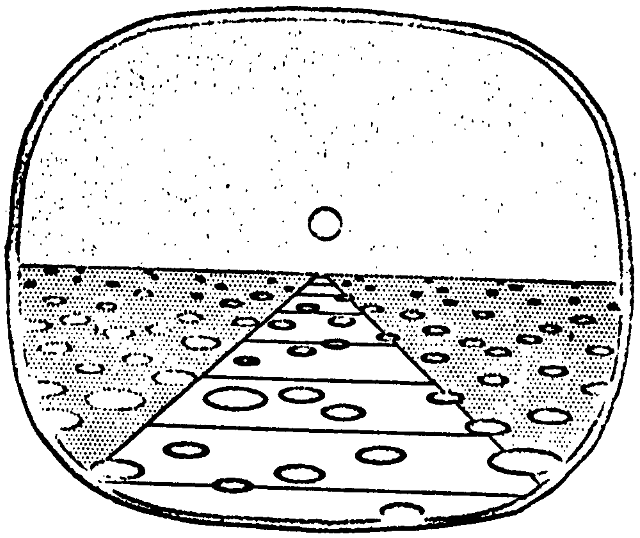


Figure 14b
Pitched Up - On Course

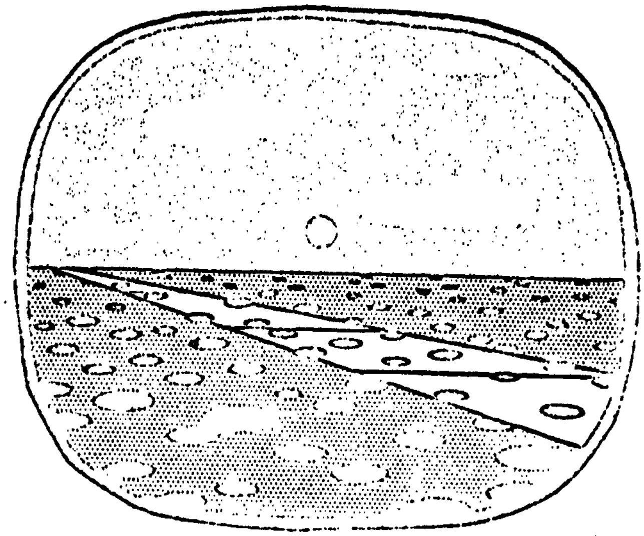


Figure 14c
Left of Course - Pitched Up
Headed to Right of Course

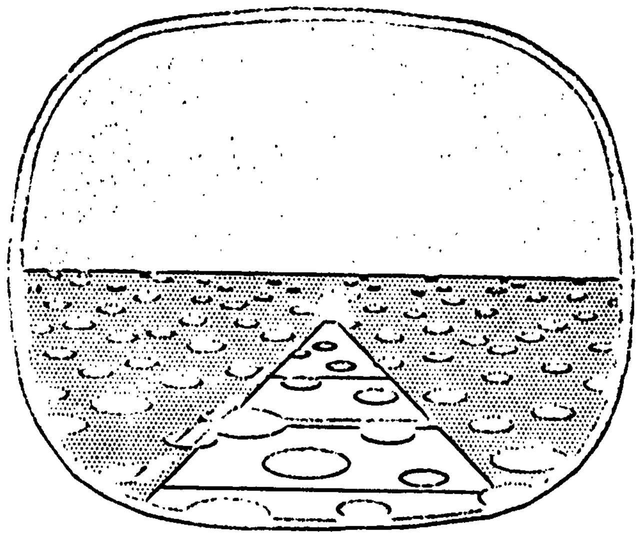


Figure 14d
Landing Display

5.1.2 Horizontal Display Symbol Description

The horizontal display is the primary source of navigational information. (See Figure 15). It is located in a position which is accessable to both the pilot and co-pilot (See figure 6). The symbols appearing and the information presented are the same for both J-50 and HU-1A with the addition of RAILS symbology in the HU-1A version.

5.1.2.1 Map Storage

A map area 1,000 miles square at 2 scales and selected portions of the same area at a third scale are provided. The photographically reduced map areas are stored on a film strip and, when viewed at the display, the full area scales are 1:250,000 and 1:1,000,000 with the partial coverage scale at 1:62,500. Map originals with the desired information content will be provided by the Signal Corps. Information as to minimum line widths and separations, information density, alphanumeric size requirements, and other pertinent data will be supplied by DAC.

The storage mechanism will be designed to facilitate film strip removal and replacement. The strip change operation will not, however, be an in-flight capability.

5.1.2.2 Acquisition Symbol

The acquisition symbol is represented by a small circle.

The position of this circle will be the position stored by the computer in the data entry mode.

DOUGLAS AIRCRAFT COMPANY, INC. EL SEGUNDO DIVISION EL SEGUNDO, CALIFORNIA

FORM 30-254 (7-51)

PRIMARY DISPLAY-HORIZONTAL

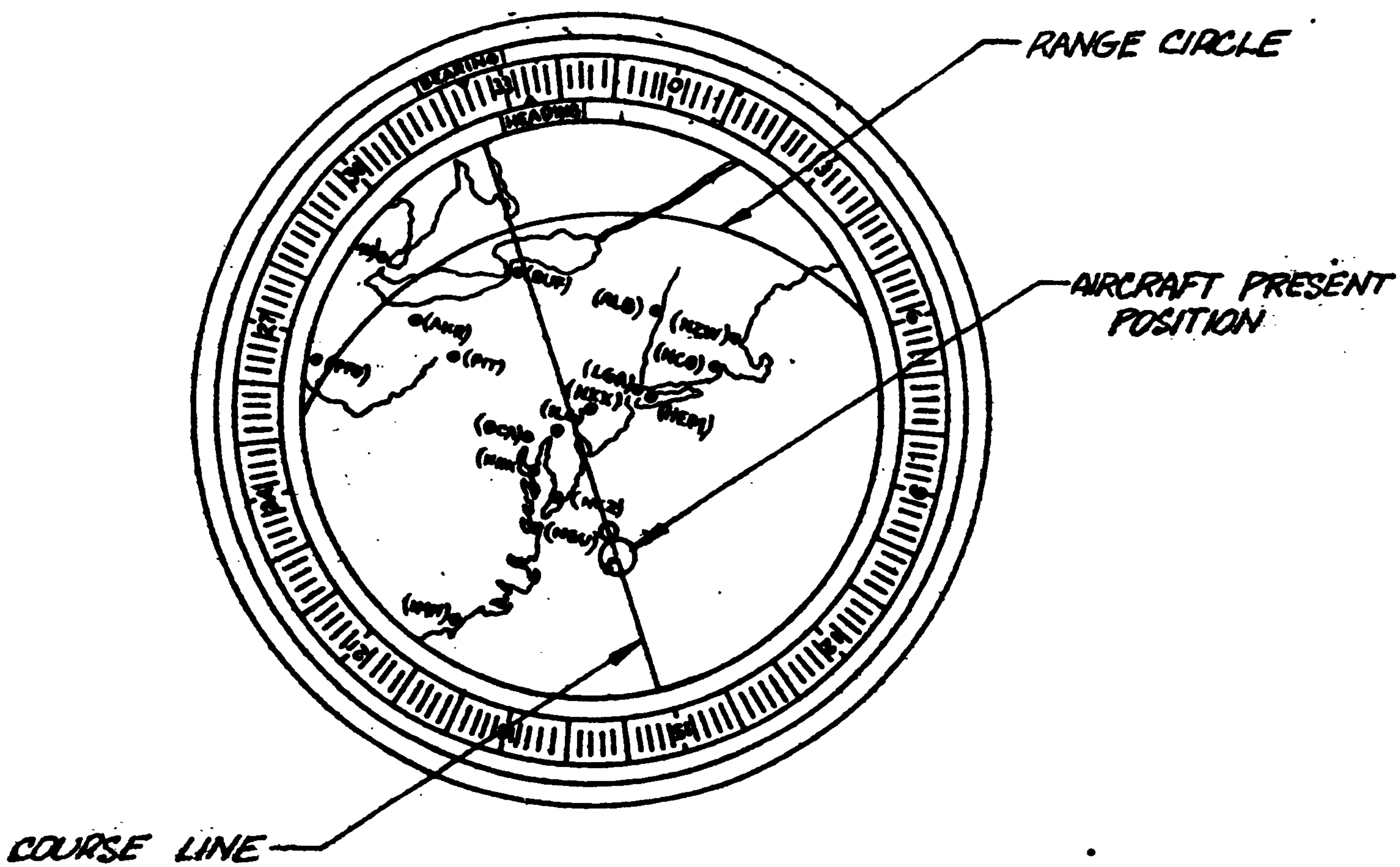


FIGURE 15 HORIZONTAL DISPLAY

5.1.2.3 Present Position Symbol

The present position symbol will represent the aircraft position and true heading. The symbol will form an approximate aircraft shape.

5.1.2.4 Course Line

The course line will appear as a line running across the display face along the same commanded course being presented on the vertical display.

5.1.2.5 Range Circle

The fuel range remaining will appear as a circle centered at the present position symbol. The circle will have a radius equivalent to the distance that can be traveled at the present rate of fuel consumption before the reserve fuel supply must be used.

When the helicopter enters autorotation, the range circle will indicate the distance that can be traveled under autorotation conditions.

5.1.2.6 Remote Area Instrument Landing System Symbols

The microwave RAILS system display capability will be a part of the HU-1A only. RAILS will take over the horizontal display in the RAILS mode of operation and all standard RAILS symbols will be displayed. (RAILS outputs to the vertical display will be utilized to position the command path described in 5.1.1.4).

5.2 SYSTEM MODE SELECTION

The mode selection controls for the display system have been organized in a logical pattern to facilitate ease of pilot operation. The location of the controls is consistant with human factors studies and a time line analysis performed during the design plan period. The grouping of the controls is such that each group is related to an independent function of the display system. With the exception of the power controls, the pilot need only select one mode from each group to accomplish a specific system mode of operation. The modes available have been selected to afford a high degree of flexibility with a minimum of control complexity. The control grouping is as follows: (See figure 6 and Exhibits 12 and 13)

5.2.1 Power Controls

Primary power for the system is controlled by a single switch located on the instrument panel. Individual circuit breakers for each sub-system will be provided for test purposes but will not be located centrally. Included in the category of power controls will be the doppler and terrain clearance radar standby-operate switches.

The switches included in this group are:

* "System Power"
* "Doppler Standby-Operate"
* "TCRS Radar Standby-Operate"

5.2.2 Navigation Mode Controls

Three sources of navigation information are provided. The "Nav Mode" controls are used to select the desired navigation mode. These controls are:

* Doppler
* Air Data
* Nav Ref.

5.2.3 Flight Path Course

Several alternatives are provided with regard to the c command course to be presented. These controls allow the pilot to select the course desired. The controls provided are:

* Take Off
* Course Hold
* Nav Course
* Bearing Command
* Homing
* Land

5.2.4 Flight Path Attitude

In all modes of operation with the exception of "Take Off" and "Land" a flight path attitude must be selected in addition to a course mode. The modes provided to control flight path attitude are:

* Max Range
* Max Endurance
* Vertical Rate

* Alt Hold
* Pre-Select Alt
* Terrain Follow

5.2.5 Flight Path Reset

The flight path reset button is provided to allow the pilot to clear from his displays the flight path symbols. This allows him to enter new commands or fly without a flight path being displayed.

5.2.6 Data Entry and Course Set

One of the primary functions of the horizontal display is to provide the input source for the navigation section of the computer. This function is obtained by utilizing the data entry and course set controls. These are:

* Present Position
* Position 1
* Position 2
* Nav Station
* Data Entry
* Course Set

5.2.7 Map Modes

The map presented on the horizontal display has two modes of operation. These are:

* Moving Map
* Fixed Map

5.2.8 **Bearing Selector**

The bearing cursor on the horizontal display has three sources of information. The bearing selector controls the source of information being displayed. This control has the following positions:

* Computed Bearing
* ADF Bearing
* OMNI Bearing

5.2.9 **Radar Display Control**

The type of radar information being displayed is controlled by the radar display control. This control has three positions which are:

* Ground Map
* Terrain Avoidance (Azimuth scan through vertical flight vector)
* Off

5.2.10 **Map Scale**

The map presented on the horizontal display has three scales. These are:

* Master
* Enroute
* Terminal

Consideration is being given to provide for a fourth scale for the HU-1A

5.2.11 **RAILS Select**

In the HU-1A, provision will be made for a button to select the RAILS landing mode. In this mode the RAILS symbology could appear on the horizontal display instead of the map.

5.3 OPERATIONAL DESCRIPTION

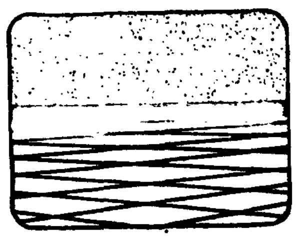
The system is capable of operating on one of several modes or combination of modes. Mode selection is performed by the pilot through the use of an integrated control network. The system is programmed to respond to the activation of these controls. Examples of the functional use of the pilot controls and their relation to the primary and auxiliary displays is presented in the following mode descriptions.

The arrangement of these controls is shown in figure 6 and Exhibits 12 and 13 for the J-50 installation, and in Exhibit 14 for the HU-1A installation.

5.3.1 Pre-Flight

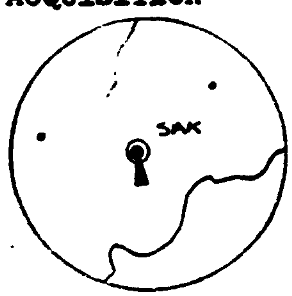
Display Appearance	Description

INITIALIZE



Normal starting procedures for the aircraft are maintained in this system. Switch "System Power" to "on". This turns on computer and display generator. Turn on sensor and other auxiliary equipment. The display will appear as shown - no flight path on the vertical display, - no course line on the horizontal display. The computer initializes with horizontal display center zeroed and map scanner vidicon center stored as present position. The A/C symbol and acquisition circle appear in the center of the horizontal situation display (HSD). All navigation "mode" buttons are in the off position; the computer will not perform the navigation solution until one of them is depressed. The selected map scale will appear on the HSD. Check should be made of systems not operative at this time.

ACQUISITION



Programming of the computer is initiated as follows:

a. Slew map to observe present position on HSD.

b. Select desired map scale for acquisition.

c. Position acquisition symbol over present position by operation of slew control.

d. Depress "Data Entry," green light will appear in button.

e. Depress "Present Position" while green light is on. This stores the coordinates of the acquired point in the computer as present position.

f. Repeat operation (d).

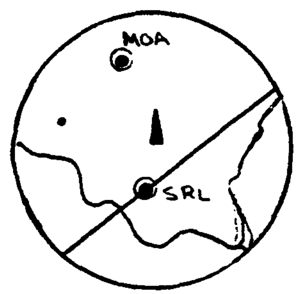
g. Depress "Position 1" while green light is on. This stores the coordinates of the acquired point in the computer as base position.

h. Position acquisition symbol over first destination similar to operations (b) and (c). Repeat operation (d).

i. Depress "Position 2," which stores acquired point in the computer as destination.

j. Similarly repeating operations (h) and (i) stores any desired position into the computer. If OMNI-DME navigation is desired, the location of the NAV-AID station must be stored in "Nav. Station" position. Otherwise, an alternate destination can be stored. Map slew is accomplished by depressing the slew button and moving the slew control handle in the direction of slew desired. When in the slew mode the aircraft symbol will disappear.

Course Set



The computer will now have sufficient coordinate data to position the aircraft symbol and course line on the navigation display when selected.

The command course is established as follows:

a. "Course Set" button is depressed. Green light will appear in button.

b. Depress position button which represents desired destination while green light is on.

c. Repeat (b) for position of desired base. (b) and (c) must not be done simultaneously.

Green light will go out after base position is selected or after 10 seconds, if both destination and base are not selected.

Continual solution of present position is accomplished by selecting one of three navigation modes; this selection should be made prior to takeoff.

a. "Doppler" - Present position is continually computed from North and East velocities received from the doppler radar. If doppler signals are temporarily lost, the system automatically reverts to dead reckoning navigation using TAS, mag. heading, and doppler remembered wind. When doppler signals are received again the system returns to pure doppler navigation.

b. "Air Data" - Present position is computed by dead reckoning using TAS, mag. heading, and manual wind magnitude and direction. Setting wind to zero and flying a "Ground Stabilized Flight Path" establishes the air mass stabilized mode.

c. "Nav. Ref." - Present position is computed from "OMNI" and "DME" information. It is required that this information be obtained from a single station the location of which is stored in the "Nav. Sta." position.

5.3.2 <u>Take Off Mode</u>

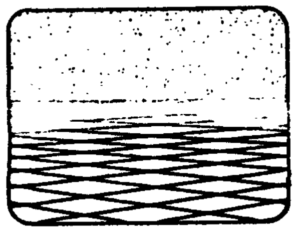
Take Off

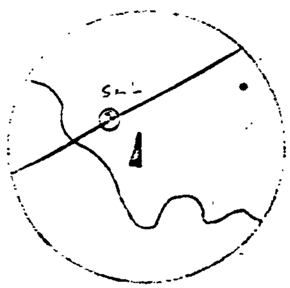
When the aircraft is in position on the runway the "Take Off" button is depressed, the flight path on the vertical display will appear and will be oriented to show a path locked at runway altitude, present heading and infinite length. As the take off run is made the flight path remains stabilized at runway altitude and heading as the aircraft flies above it. At an altitude of 1000 feet the system will automatically enter the "Cruise" mode.

In the helicopter system the "take off" command path will most often be determined by the vertical rate control and selected rate of climb (See paragraph 5.3.3).

5.3.3 Cruise Mode

Cruise
(No Flight Path)





The cruise mode is the normal flight mode. After takeoff, the computer automatically enters the cruise mode; in this mode no flight path will appear on the vertical situation display (VSD) until a "Flight Path Course" and "Flight Path Attitude" are selected. The procedure for establishing a command flight path on the VSD in the cruise mode is as follows:

a. Select a "Flight Path Course" other than "Takeoff" or "Land". Only one may be selected.

   1. "Nav. Course" establishes a flight path which corresponds to the "Course Set" previously selected. If the pilot flies the command flight path on the VSD, he will be on course on the HSD.

   2. "Present Course" establishes a flight path which commands the pilot to fly the existing groundtrack.

   3. "Bearing Command" establishes the command flight path to follow the bearing information chosen with the "Bearing Selection" dial. For example, if "OMNI" is selected under "Bearing Selection" and "Bearing Command" is depressed, the command flight path will be along the OMNI station radial bearing

received at the time the "Bearing Command" button was selected.

4. "Homing" establishes the command flight path to home on the bearing station selected ("OMNI" or "ADF").

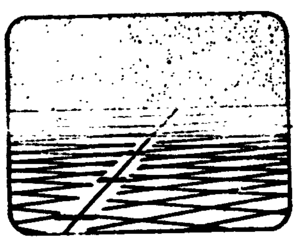
In all the above four cases the flight path course selected for the VSD will automatically change the course line on the HSD to correspond to it.

b. Select a flight path attitude. Only one may be selected.

1. "Present Alt." holds the flight path at the altitude of the aircraft when the button is depressed.

2. "Pre-Select Alt" sets the flight path altitude to that previously chosen by the "Altitude Set" dial on the Auxiliary Altitude Display.

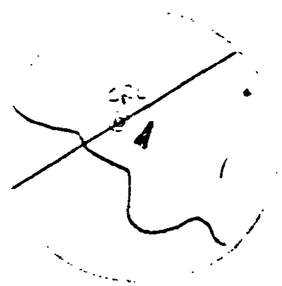
Typical Cruise



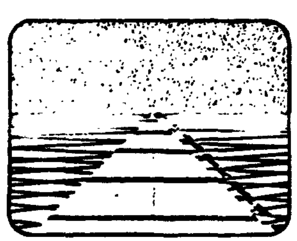
3. "Terrain Follow" commands the flight path in pitch and altitude to follow the terrain at an altitude previously selected by the "Altitude Set" dial on the Auxiliary Display. The "Terrain Follow" button will not operate unless the "Alt. Set" indicator is less than 1000 feet.

4. "Vertical Rate" commands the flight path to the proper pitch angle which produce the rate of climb set into

Typical Cruise



Flight Path
With Speed Ribbon



the rate of climb set counter.

In the above four modes, the speed marker ribbon on the VSD will be commanded by the command speed set counter. The ribbon moves at a rate proportional to difference between present true air speed and command speed. If command speed is set to zero, no ribbon will appear on the VSD.

5. "Max Endurance" commands an optimum aircarft speed for a maximum endurance flight at present flight conditions, independent of the command speed set counter. True air speed error is displayed by the command air speed error markers on the VSD. Command TAS is also indicated on the Auxiliary Air Speed Indicator.

6. "Max Range" is similar to "Max. End.". It commands true air speed which yields a maximum range. In the max. range and max. end. modes the altitude of the flight path remains at the altitude of the aircraft when the button was depressed. The command altitude marker on the auxiliary display is commanded to the same altitude.

At any time during the flight, either the "Fix Map" or "Moving Map" mode may be selected.

a. "Fix Map" - On the HSD the aircraft symbol moves over a stationary map display. As the symbol moves toward the edge of the display, the map shifts to the next position and the symbol appears to jumb back to the opposite edge. This cycle is repeated as long as the fixed map mode is retained.

b. "Moving Map" - The aircaft symbol remains fixed on the display while the map moves beneath it.

In both of these modes the orientation of the map on the display with respect to the aircraft heading is controlled by the "Rotate Map" switch on the horizontal display.

The scale of the map displayed is chosen by selecting one of the following:

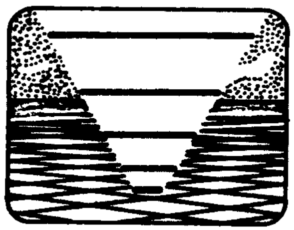
"Terminal" - Large scale map (6 miles)

"Enroute" - Medium scale map (24 miles)

"Master" - Small scale map (96 miles)

Changing from one scale to another while in flight automatically repositions the map to the new scale at the aircraft present position.

5.3.4 Land Mode



Fixed Wing Landing

When the aircraft is approaching the landing field the "Land" button is selected. In this mode the flight path on the VSD is commanded by the localizer and glide slope deviation signals.

Field altitude is set into the computer and pull-up marker will be displayed on the flight path when the aircraft is 250 feet above the runway. At this time the pilot will continue to flare-out and touch-down under VFR conditions.

Helicopter Landing

The helicopter may land on the glideslope in the same manner as the fixed wing. Provision is also made for the helicopter to land by RAILS (Remote Area Instrument Landing System) information. RAILS controlled landing is accomplished by depressing the RAILS button before selecting the "Land" button. The regular RAILS controls must also be set according to standard operating procedure. The RAILS symbology will be displayed on the horizontal display instead of the map. The VSD flight path will also be commanded by the RAILS in this mode. In order for the helicopter pilot to obtain the maximum information from the flight path while in this mode, it is

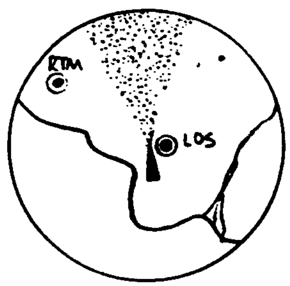
Map slew is used when it is desired to view some portion of the map other than that which is in the vicinity of the aircraft. The slew mode is entered by depressing the "Slew" button. The map drive is transferred from present position error outputs of the computer to the slew control stick. The map is then driven in the direction in which the slew stick is moved. Releasing the slew stick stops the map. When in the slew mode, the "Map Selection" may be operated as above if the control stick is in its center position; the position appearing on the new map scale will be the same as that which was displayed on the old map scale when the new scale was called for. The map will display present position when the slew mode is disengaged; this is accomplished by selecting a "Map Mode".

The slew control stick is also used to displace the aircraft symbol with respect to the display center. This may be done at any time by moving the control stick in the direction desired. The slew button is not depressed for this operation.

required that he fly beneath the path the same way that he normally flies above the path. (See illustration).

5.3.5 **Radar Display**

A video radar sweep may be superimposed on the HSD over the map. Two types of displays are provided.



a. "Radar Map" - Terrain features are displayed by radar mapping technique; the scale of the radar map matches the scale of the displayed map.

b. "Terrain Avoidance" - The radar sweeps in asimuth and indicates the location of the terrain obstacles in the flight plane of the aircraft. The scale of the radar sweep matches the scale of the displayed map.

The horizontal radar display may be turned off by selecting "Radar Display Off".

5.3.6 **Reset**

Depressing the "Reset" button removes the flight path from the VSD and the course line from the HSD. It also allows the operator to reset the flight path commands.

5.3.7 <u>Aircraft Stabilized - Ground Stabilized - Air Mass Stabilized Flight Path</u>

1. Switching to the "Aircraft Stabilized Mode" fixes the near end of the flight path of the VSD to the aircraft. The HSD course line remains as previously set. In this mode the vertical display flight path gives heading command information and vertical displacement from the flight path, but no horizontal displacement information.

2. Switching to the "Ground Stabilized Mode" establishes a flight path which is fixed with respect to the ground.

3. Switching to "Air Mass Stabilized Mode" establishes a flight path which is fixed with respect to the air mass. In this mode air data is utilized for navigation and no correction is made for wind.

5.3.8 <u>System Capability in D-Mode</u>

D-Mode of Terrain Avoidance Radar operations is defined as "The aircraft flies at a desired, predetermined absolute or barometric altitude. The pilot changes heading at his discretion to take advantage of the terrain. The objective of this is for the aircraft to remain in defilade during the longest possible portion of the flight."

In the ground stabilized and air mass stabilized flight path modes, once the aircraft leaves the flight path in azimuth, the present system provides azimuth information on the horizontal situation display and vertical command information only by the voice and light warning systems when the aircraft has reached the point of requiring maximum pull up to clear an obstacle. There may be no push-over command since the flight path is not necessarily visible on the vertical display.

In the aircraft stabilized mode, azimuth information is provided on the horizontal display and azimuth and vertical commands can be displayed by the flight path. This display is not recommended since the aircraft stabilized flight path is not a recognized ANIP concept, and the use of it in this manner changes the meaning of the flight path. The vertical command is with respect to terrain while the azimuth command can only be with respect to navigation to the desired destination, or remain zero since sensors are not available to provide information to create a curved path which is optimum for D-Mode operation.

A higher capability of D-Mode operation, which is not part of the present design, is included in Exhibit 36.

6.0 FACTUAL DATA - SYSTEM INSTALLATION

Location of equipment in the J-50 and HU-1A is shown in Figures 16 and 17. The aircraft will be modified to provide maximum accessibility for installation, removal and maintenance as well as providing for maximum crew effectiveness.

Details of installation provisions, cooling provisions and interconnect wiring will be determined on a model shop basis after receipt of the aircraft. A wooden mockup of the J-50 fuselage from the baggage compartment forward has been constructed to aid in general arrangement of instruments and controls. This mockup will also serve to take the first rough cut at equipment installations. Figures 18, 19, 20, 21, and 22 are photographs of the mockup.

6.1 J-50 Aircraft Description & Modification

6.1.1 The J-50 Beechcraft Twin - Bonanza is an all metal, six-place, low wing, twin engine cantilever monoplane, with retractable triangle landing gear and full complement of standard engine and flight instruments.

The aft two seats will be removed and the instrument panel revised for the display system installation.

a. Power Plant: Two Lycoming six-cylinder 1650-480-A1B6 engines rated at 320 hp at 3200 rpm at sea level and 340 hp at 3400 rpm for take-off.

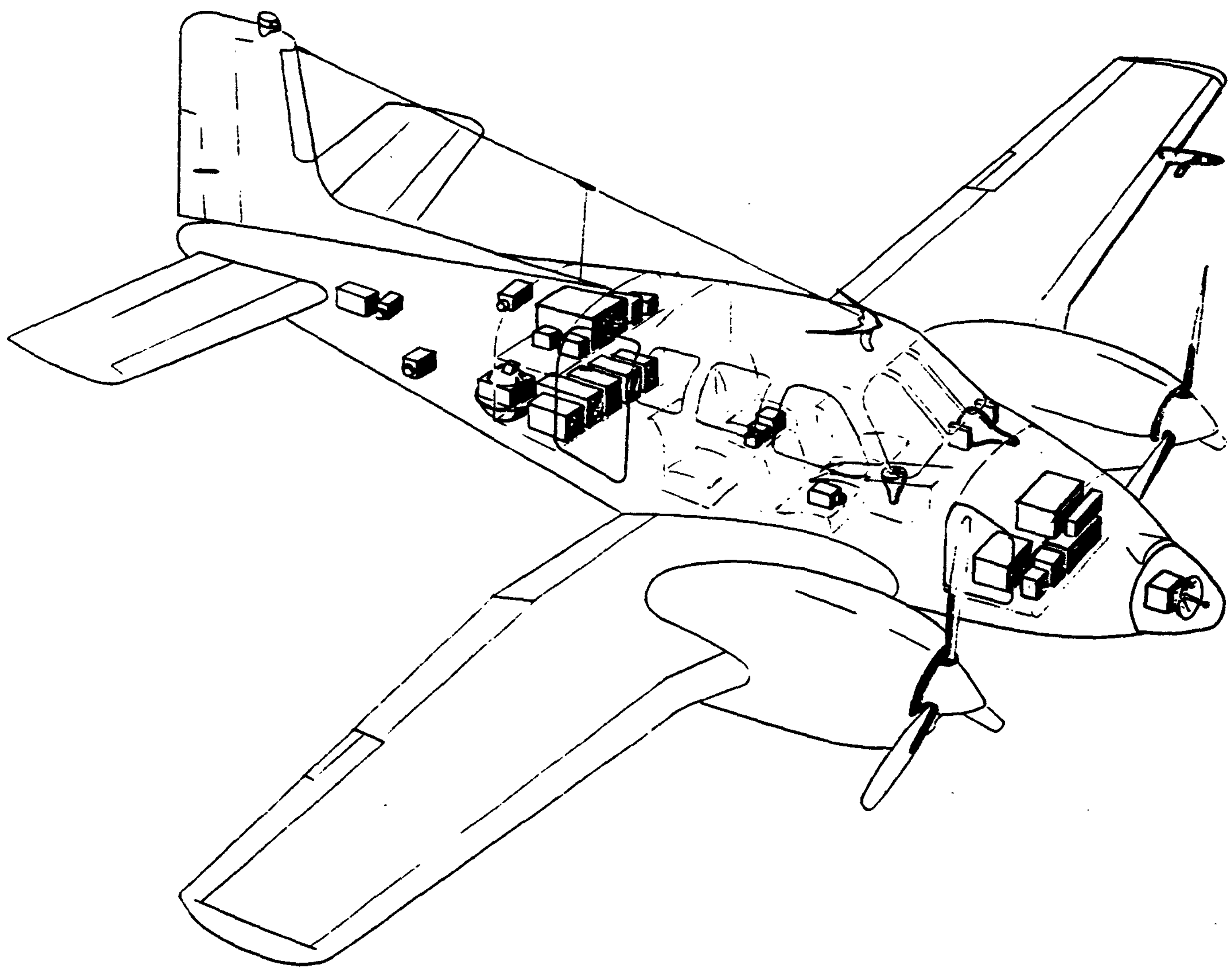


FIGURE 16, J-50 EQUIPMENT LOCATION

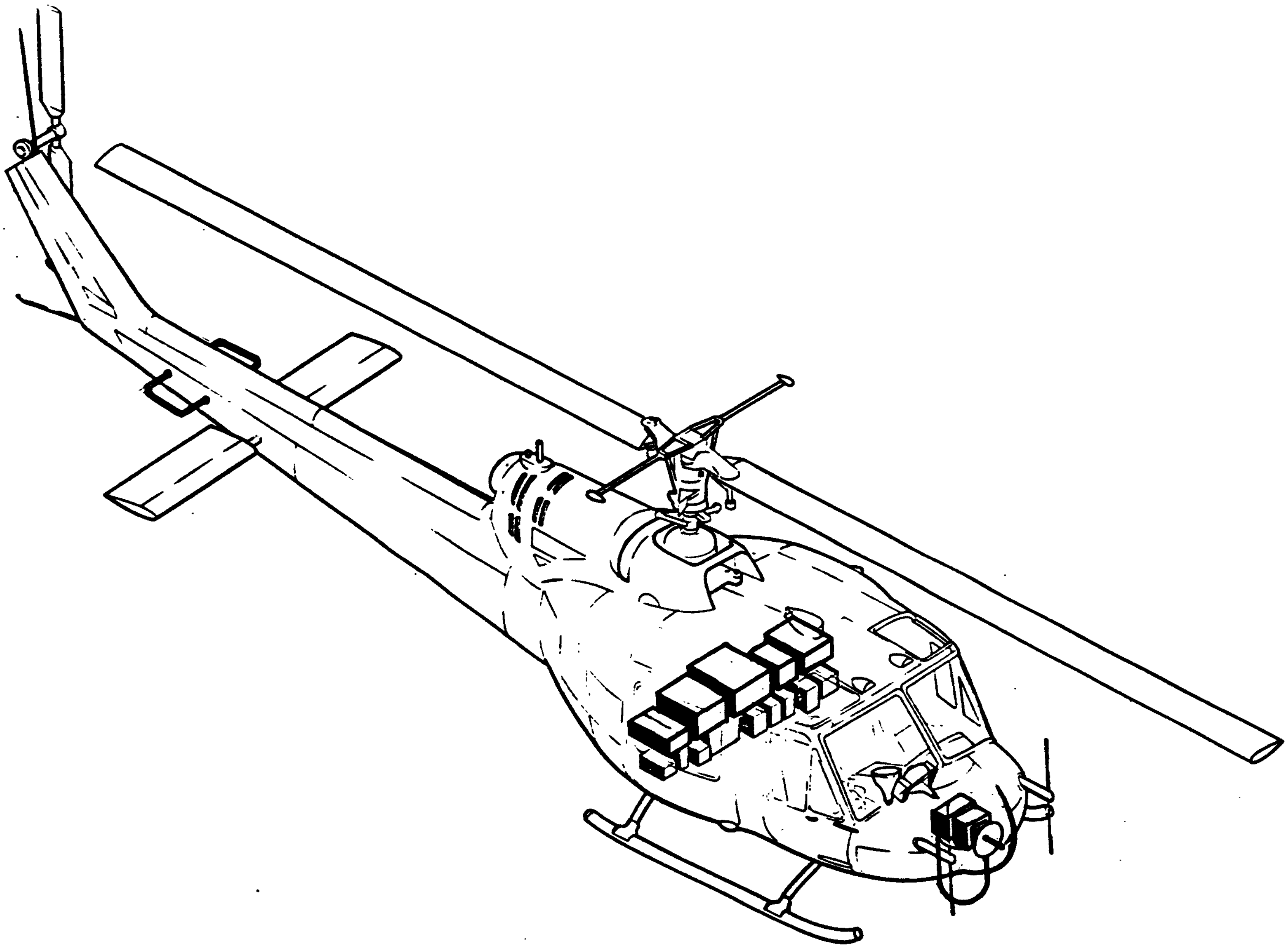


FIGURE 17. HU-1A EQUIPMENT LOCATION

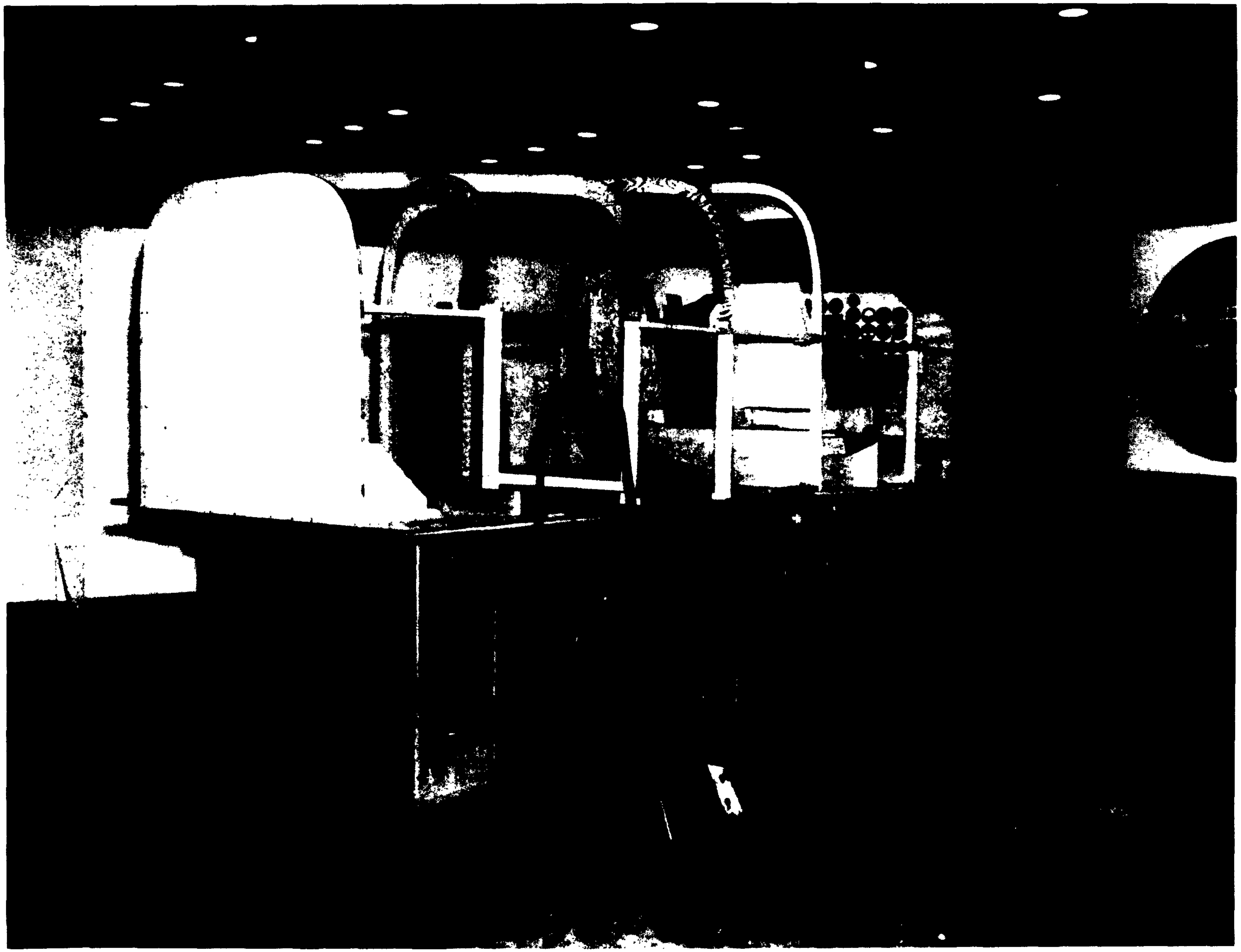


Figure 18. MOCKUP - LOOKING FWD., R.H. SIDE

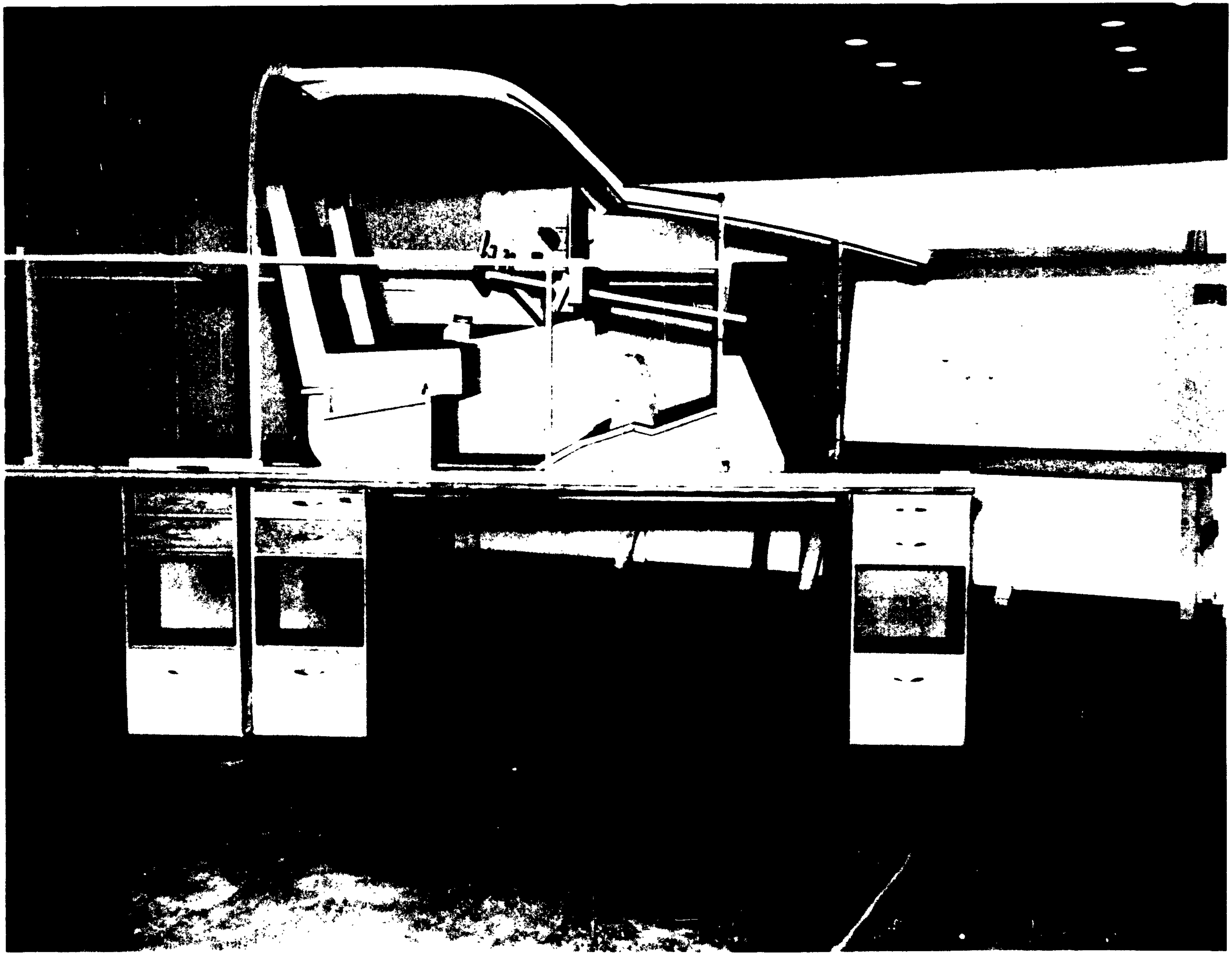


Figure 19. MOCKUP - LOOKING FWD., R.H. SIDE

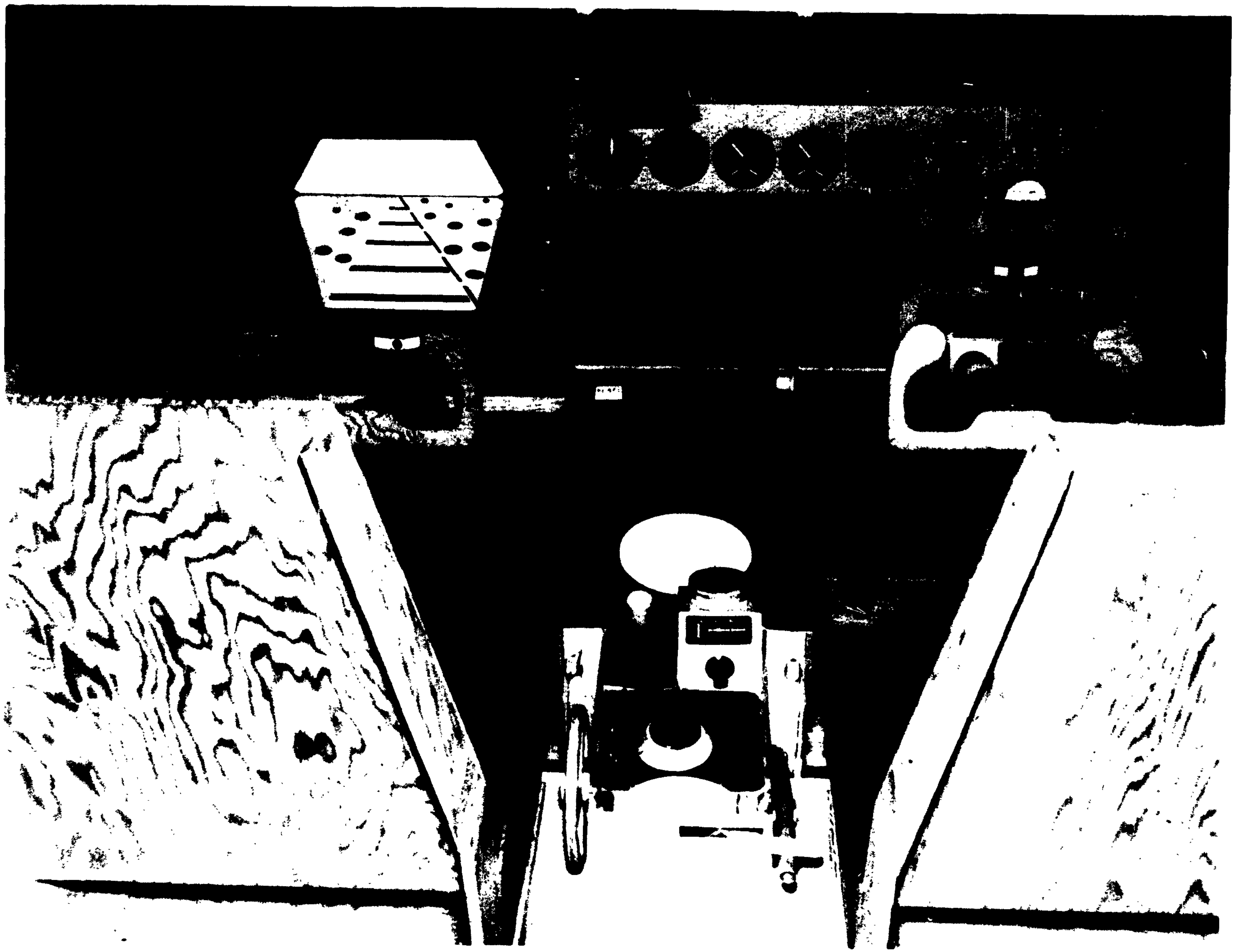


Figure 20. MOCKUP - FULL INSTR. PANEL

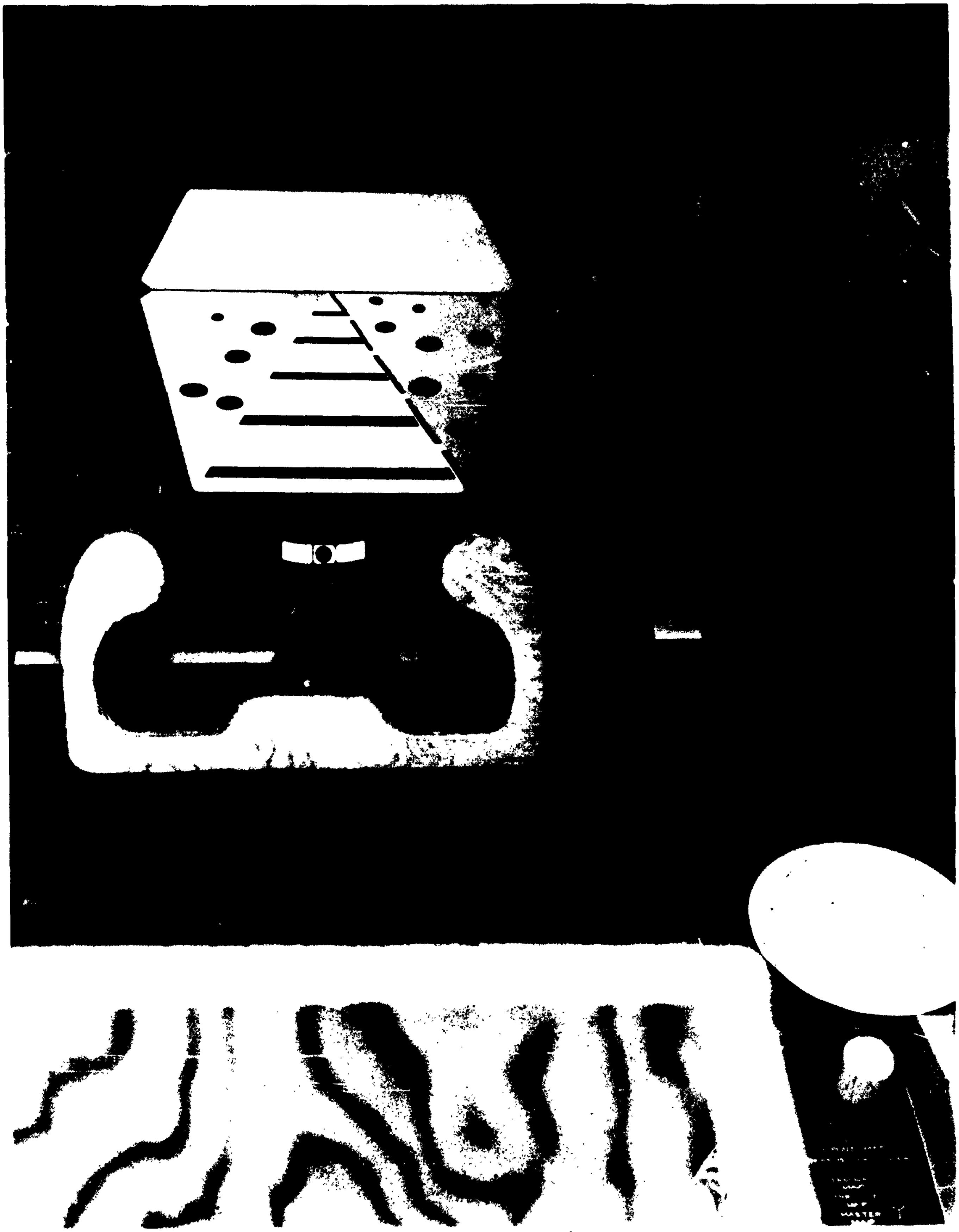


Figure 21. MOCKUP - PILOTS INSTR. PANEL

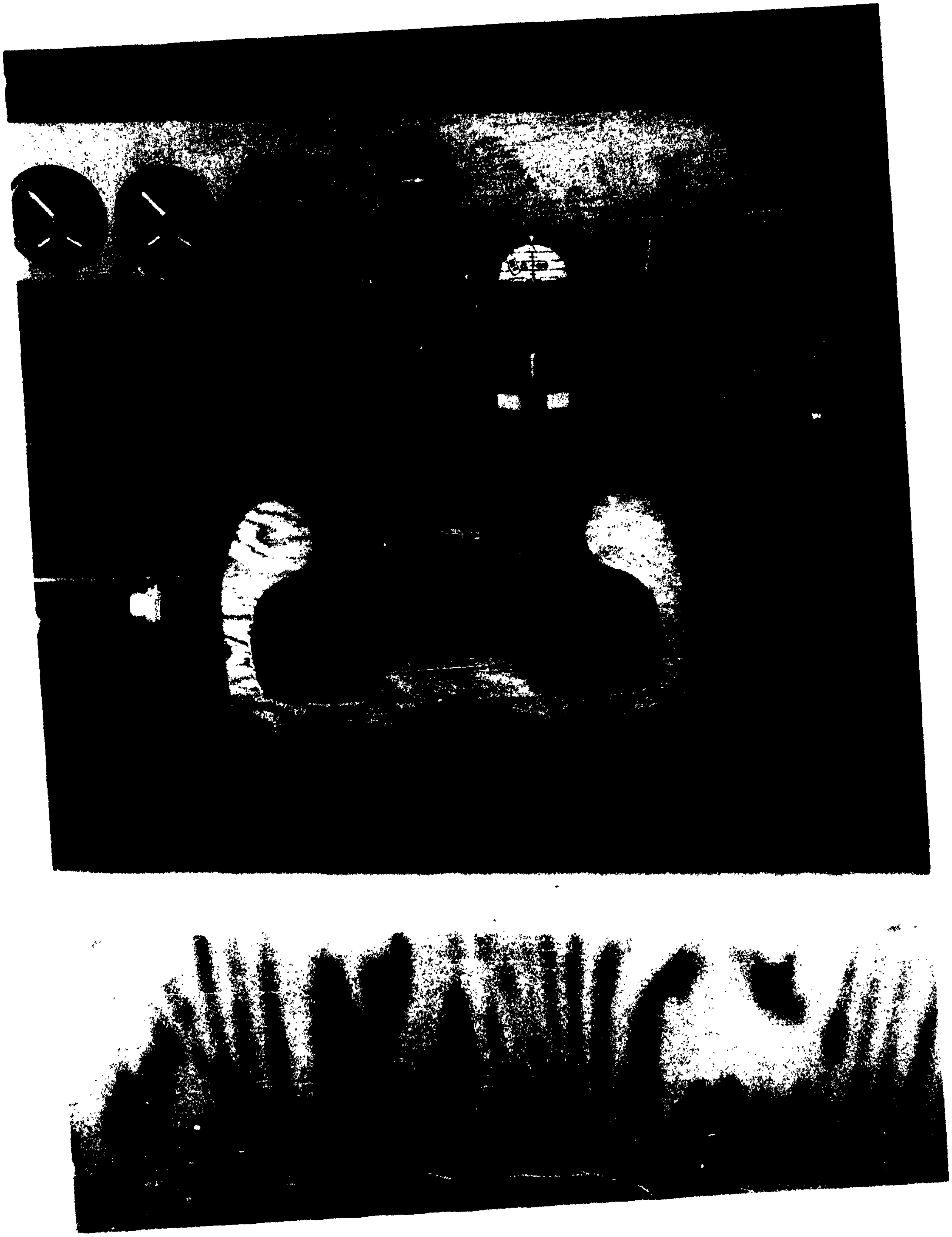


Figure 22. MOCKUP - CO-PILOTS INSTR. PANEL

b. Propellers: Two Hartzell 3-blade, full feathering, constant speed, hydraulically controlled propellers.

c. Fuel: 100/130 minimum octane avaition gasoline. Two 44 gallon main tanks and two 71 gallon auxiliary tanks contain the usable fuel (146 gallons maximum for the display system installation).

d. Manuevers: This is a normal category airplane. Aerobatic maneuvers, including spins, prohibited.

e. Maximum Weight: 7300 lbs. (Take-Off) 7000 lbs. (Landing).

f. Controls: Conventional 3 control system with dual "W" type control wheels.

6.1.2 Equipment Location

Installation of the equipment in the J-50 is shown in Exhibit 25. The aircraft modification can be divided into 7 general areas:

Nose - Revise the forward nose structure for the installation of the terrain avoidance radar antenna and associated radome.

Forward Equipment Compartment - Add equipment racks for mounting new equipment.

Instrument and Center Console Panels - Remove the instrument panel and sub-panel. Add display system instruments for the pilot and conventional instruments for the co-pilot. Revise the center console panel, i.e., re-route trim cables and relocate emergency landing gear down pump, oil shutoff switches, generator circuit breakers and landing gear circuit breakers. Add horizontal display instruments.

Placement of the horizontal situation display in the position shown in Figure 6 was determined by the following two factors.

(1) It was desired to place the horizontal situation display in the horizontal plane to retain the ANIP concept that information from a particular plane should be displayed in that plane.

(2) It was desired to keep the modifications of the aircraft to a minimum.

The optimum position for this display in a production configuration would be in a horizontal plane directly below the vertical display. This position was not chosen for this system installation because it would require a major modification to the control system.

Cabin - Revise pilot and co-pilot seat removal installation to prevent interference with the new center console. Remove the aft two passenger seats.

Aft Fuselage - Revise the lower airframe structure for the installation of the Doppler Receiver-Transmitter. Add the autopilot servos. Add the main and standby inverters.

Wing - The C-11 flux valve will be installed in the wing to minimize interference problems. The angle of attack sensor will be installed in the wing to keep the sensor from being affected by propeller blast.

6.2 HU-1A Aircraft Description

Installation of the equipment in the HU-1A is shown in Figure 11 and in Exhibit 26. A wide cabin with large volume permits the utility type aircraft to be used for the evaluation of the proposed display system. Weight and balance of the aircraft has been obtained in accordance with the TM-55-1520-207-10 Operator's Manual. Performance information may also be obtained from this manual.

6.3 Power System Description

6.3.1 J-50

The primary power system in the Beechcraft J-50 airplane is 28 V.D.C. powered from two engine driven paralleled generators. Battery D.C. power is provided from two 12 volt, 33 ampere hour batteries connected in series. A 115 volt A.C. 400 C.P.S. power source is not provided.

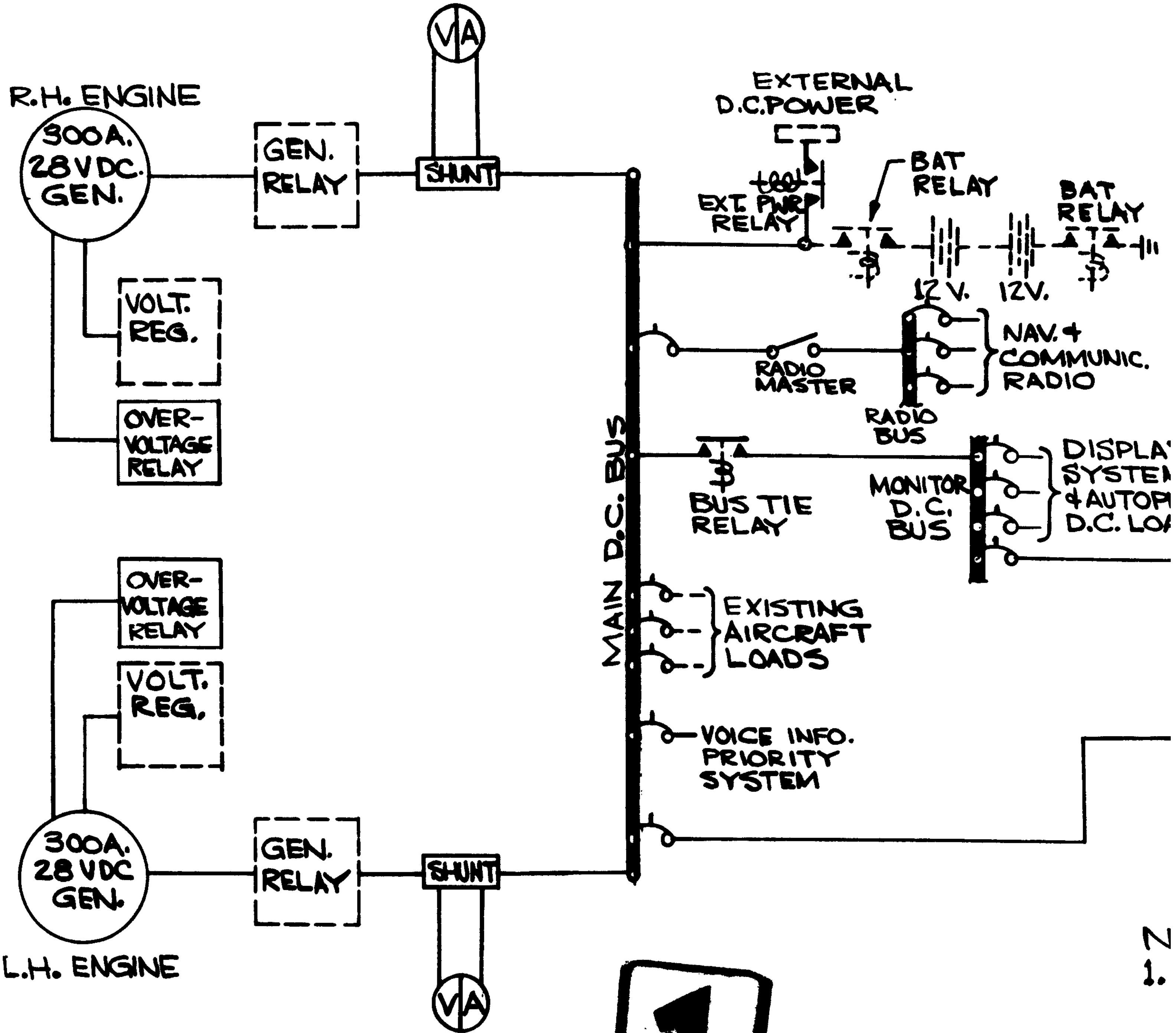
The 100 ampere generators that are furnished with the airplane are replaced with 300 ampere generators to supply the added AAAIS load. The existing voltage regulators and generator relays are retained for control of the new generators.

A 3000 VA main inverter is provided to power the added 115 volt 400 C.P.S. load. A 500 VA emergency inverter is provided to power the A.C. loads required for communication radio, navigation radio and instruments in case of failure of the main inverter. Refer to Figure 23 for the schematic of the revised power system.

The maximum continuous 28 V.D.C. load (Take-off and climb) on the two paralleled generators is as follows:

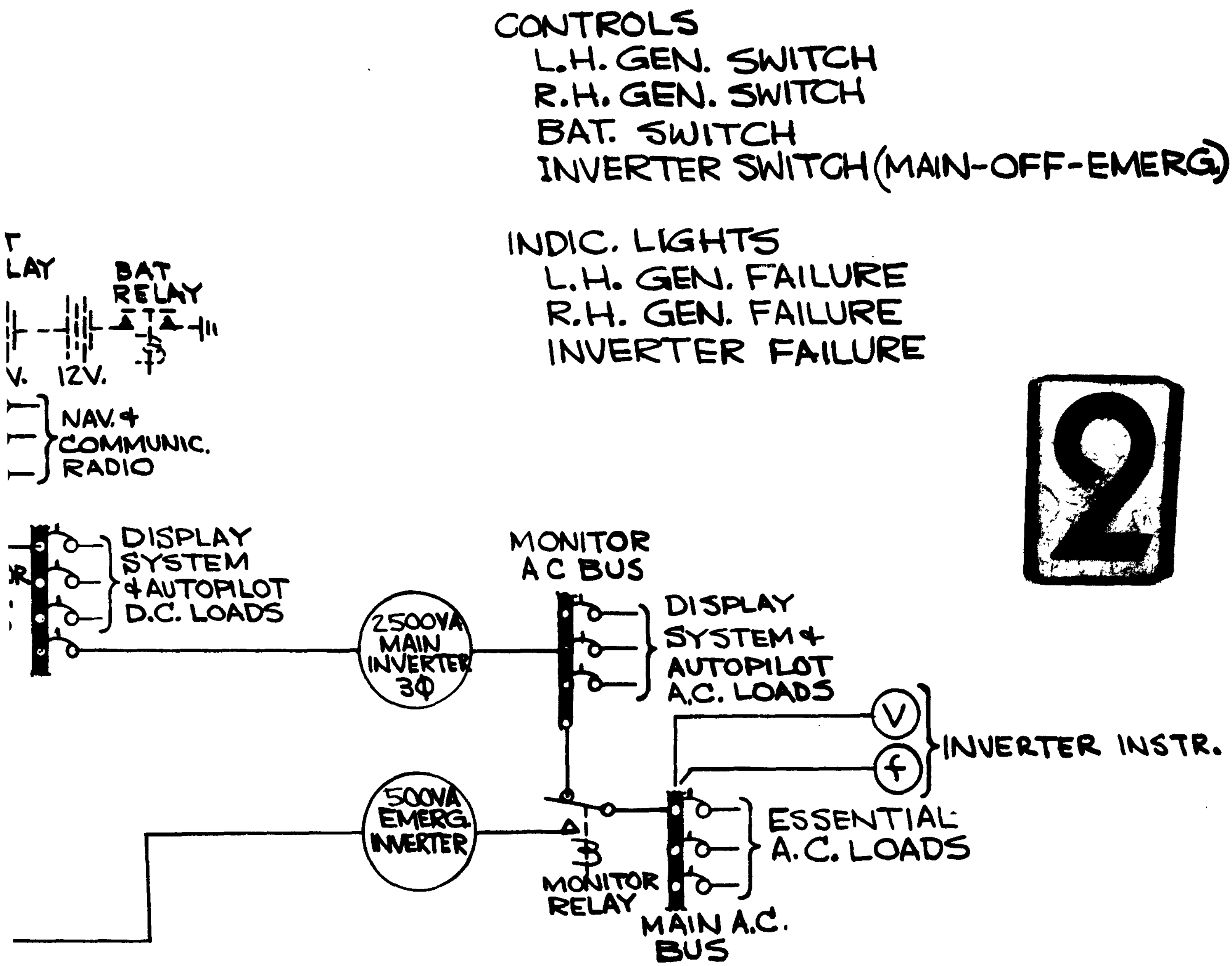
Existing loads and added radio loads	81 A.
3000 VA main inverter	163 A.
Display System D.C. load	55 A.
ASW-12 A.F.C.S.	15 A.
Total	314 A.

J-50 AIRPLANE ELECTRICAL POW



1

...ICAL POWER SYSTEM



NOTE
1. DOTTED LINES INDICATE EQUIPMENT FURNISHED WITH AIRPLANE PREVIOUS TO MODIFICATION.

FIGURE 23

6.3.1 (J-50 Continued)

The normal continuous 28 V.D.C. load (Cruise Condition) is as follows:

Existing loads and added radio loads	62 A.
3000 VA main inverter	163 A.
Display System D.C. loads	55 A.
ASW-12 A.F.C.S.	15 A.
Total	295 A.

The continuous output of the two paralleled 28 V.D.C. generators is:

2 X 300A. X .9 = 540 A.

The display system and A.F.C.S. electrical loads are automatically monitored upon failure of one generator. The maximum continuous 28 V.D.C. load with one 300 ampere generator operating is as follows:

Existing loads and added radio loads	81 A.
Emergency 500 VA inverter	35 A.
Total	116 A.

Upon failure of both generators, remaining non-essential loads must be manually switched off in order that battery power for essential loads be available.

6.3.1 J-50 (Continued)

The maximum continuous load on the 3000 VA main inverter is as follows:

C-11 Compass System	95 VA
D.M.E.	240 VA
AN/ARC-73 VHF Nav/Com Radio	26 VA
Terrain Clearance Radar System	900 VA
Doppler Radar	125 VA
Computer	340 VA
Display Generator	350 VA
Airspeed Display Synchro	35 VA
Vertical Displacement Gyro	37 VA
Angle of Attack System	14 VA
Air Data System	50 VA
Altitude Display Synchro	35 VA
Fuel Flow Sensors	40 VA
ASW-12 AFCS	138 VA
Electric Horizon	45 VA
Map Scanner	50 VA
SCAT Signal summing unit (Provisions Only)	115 VA
Total	2635 VA

The maximum continuous load on the emergency 500 VA inverter is as follows:

C-11 Compass System	95 VA
Electric Horizon	45 VA
D.M.E.	240 VA
AN/ARC-73 VHF Nav/Com Radio	26 VA
Total	406 VA

Transfer from main to emergency inverter will be accomplished manually.

DOUGLAS AIRCRAFT COMPANY, INC. EL SEGUNDO DIVISION EL SEGUNDO, CALIFORNIA

J-50 Power System Added Components

	No. Req	Size			Weight (Each)
		Width	Lenghth	Height	
Bendix 30E20-11, 300 Ampere Generator	2	6 9/16 (Dia.)	11 13/32		46#
3000 VA 3ϕ Inverter	1	7 1/4"	18"	11"	58#
500 VA Inverter	1	6 1/2"	13"	8 1/2"	25#
D.C. Bus Tie Relay	1	3 5/16"	3 5/8"	4 5/8"	2.5#
A. C. Monitor Relay	1	2 11/16"	3"	3 5/16"	0.8#
A.C. Voltmeter	1	2" (Dia.)	2 9/16"		0.7#
Frequency Meter	1	2" (Dia.)	4"		1.1#
Voltage/Frequency Selector Switch	1	2" (Dia.)	1 5/8"		0.2#
Overvoltage Relay	2	2 15/16"	4 55/64"	4 27/32"	1.8#
External Power Relay	1	2 7/16"	5 1/2"	4 1/2"	2.6#
Generator Field Relay	2	4 1/2"	5"	4 1/2"	3.0#
Ammeter Shunt	2	1 3/4"	3 1/4"	1 5/8"	0.3#
D.C. V/A Meter	2	2"(Dia.)	3"		1.0#

6.3.2 HU-1A:

The primary power system in the HU-1A helicopter is 28 VDC powered from a transmission driven 300 ampere main generator and an engine driven 100 ampere standby starter/generator. DC power is also provided from a 24 volt, 24 ampere hour battery.

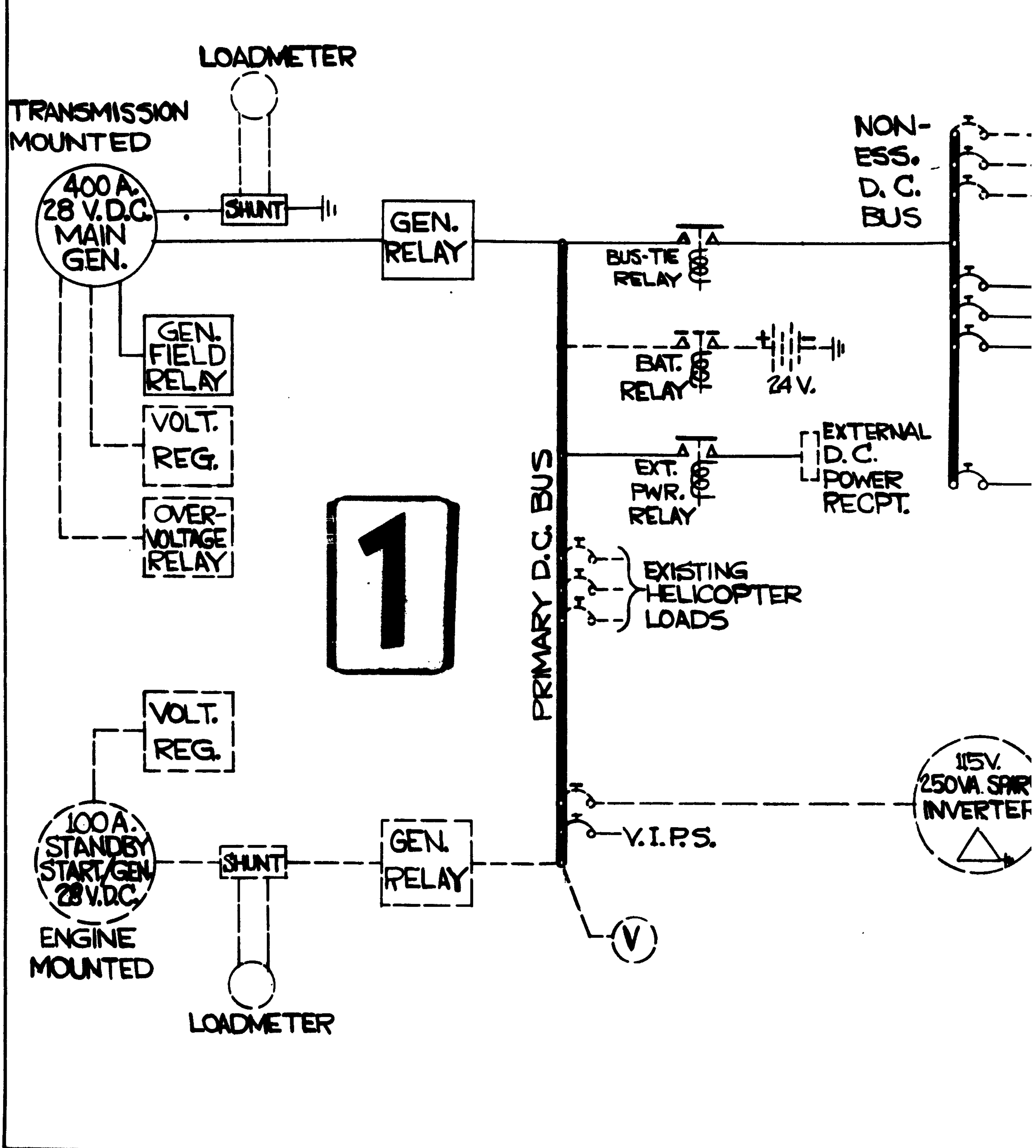
A.C. Power is supplied from a 250 VA, 115 volt main inverter and a 250 VA, 115 volt non-operating spare inverter.

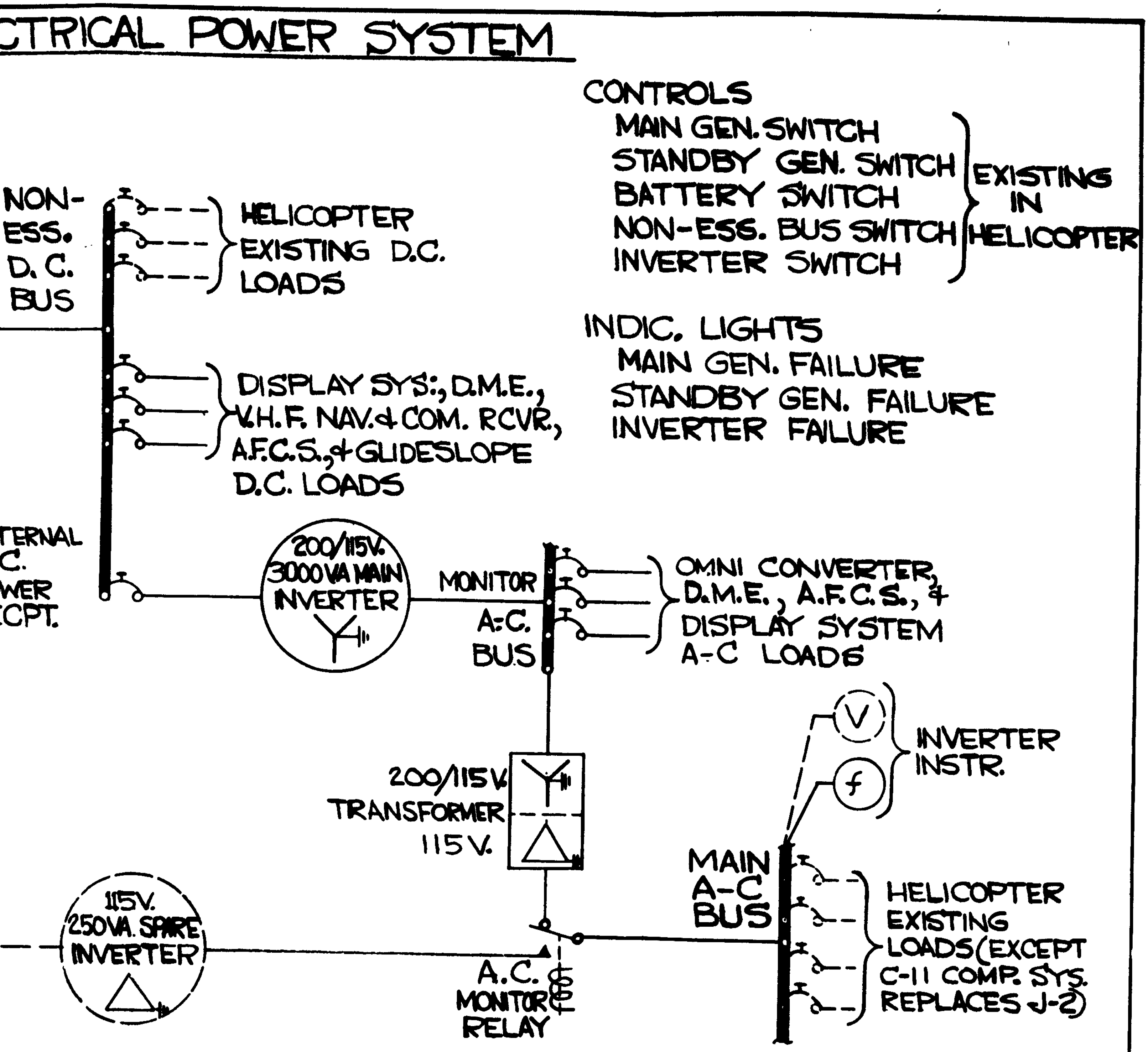
The 300 ampere main generator that is furnished with the helicopter will be replaced with a 400 ampere unit to supply the added AAAIS load. The existing voltage regulator and over-voltage relay will be retained for control of the new generator. The 100 ampere standby generator and controls will be retained without change.

The main 250 VA 115 Volt inverter will be replaced with a 3000 VA, 200/115 volt, 3 phase unit to power the added AAAIS load. The spare 250 VA 115 volt inverter will be retained to power the helicopter existing (essential) AC loads in case of failure of the main inverter.

Refer to Figure 24 for the schematic of the revised power system.

HU-1A ELECTRICAL





NOTE:
1. DOTTED LINES INDICATES EQUIPMENT FURNISHED WITH HU-1A PREVIOUS TO MODIFICATION.

FIGURE 24

6.3.2 HU-1A (Continued)

The maximum continuous 28 VDC load (take-off) on the 400 ampere main generator will be as follows:

Existing loads & added radio loads	155.A.
3000 VA main inverter	157.A.
Display System D.C. load	31.A.
ASW-12 A.F.C.S.	15.A.
Total	358.A.

The normal continuous load during cruise condition will be substantially the same as the load during take-off.

The 100 ampere standby generator is automatically connected to the primary D.C. bus upon failure of the main generator. At the same time, the existing non-essential loads, the display system loads, AFCS, DME, VHF navigation/communication receiver, and the 3000 VA main inverter loads will be automatically monitored. The maximum 28 VDC load with the 100 ampere standby generator operating will be as follows:

	2 Min.	30 Min.
Existing Loads	114.6	85.7
Additional Load on Spare Inverter	2.5	2.5
V.I.P.S.	0.5	Negl.
Total	117.6	88.2

Upon failure of both generators, the portion of remaining loads that are not required must be manually switched off in order that battery power for essential loads be available.

6.3.2 HU-1A (Continued)

The maximum continous load on the 3000 VA main inverter will be as follows:

Existing HU-1A loads	130 VA
Additional Compass load	60 VA
D.M.E.	240 VA
VHF Nav Radio OMNI converter	26 VA
Terrain clearance radar	900 VA
Doppler Radar	125 VA
Computer	340 VA
Display Generator	350 VA
Vertical Displacement Gyro	37 VA
Airspeed Display Synchro	35 VA
Altitude Display Synchro	35 VA
Air Data System	50 VA
Fuel Flow Sensor	20 VA
ASW-12 AFCS	138 VA
Map Scanner	50 VA
Total	2536 VA

The maximum continous load on the spare 250 VA inverter will be as follows:

Existing HU-1A loads	130 VA
Additional Compass load	60 VA
Total	190 VA

Transfer from main to spare inverter will be accomplished manually.

6.3.2 HU-1A (Continued)

POWER SYSTEM Added or replaced components

Item	No. Req.	Size Width	Length	Height	Weight (each)
Jack & Heintz type 30010 28 VDC Generator Modified to provide 400A. cont. output	1	8"	12"	8"	52#
3000 VA, 200/115 volt 3 phase main inverter	1	7 1/2"	18"	11"	58#
Generator Relay 600 A.	1	4"	5 1/2"	3 7/8"	3.7#
Generator Field Relay	1	4 1/2"	5"	4 1/2"	3.0#
D.C. Bus Tie Relay	1	3 5/16"	3 5/8"	4 5/8"	2.5#
External Power Relay	1	2 7/16"	5 1/2"	4 1/2"	2.6#
Loadmeter Shunt	1	1 3/4"	3 1/4"	1 5/8"	0.3#
200/115V. Wye to 115V Dèlta Transformer, 250VA	1	2"	2"	3"	2.5#
Frequency Meter	1	2" (Dia)	4"	-	1.1#
A.C. Voltage/Frequency Selector Switch	1	2" (Dia)	1 5/8"	-	0.2#
A.C. Monitor Relay	1	2 11/16"	3"	3 5/16"	0.8#

6.4 Weight and Balance

Weight and balance studies of the equipment installations shows them to be compatible with the center of gravity limits and gross weights of the aircraft. Center of gravity shift limits for the J-50 are indicated on the scope drawing of Exhibit 25.

The detail weight and balance statements are included in Exhibits 27 and 28.

6.5 J-50 Performance Summary (data based on J-50 Flight Handbook 50-590130-3, dated Nov. 15, 1960)

Take-off Weight (Max Gross) (lb)		7300
Minimum Take-off Distance (20° Flap)(No Wind)		
Ground Roll	(ft)	1260
Total over 50 ft. obst.	(ft)	1640
Stalling Speed (Power-off)		
Gear & Flaps up	(mph)	95
Gear & Flaps down	(mph)	85
Rate-of-Climb		
Two Engines at Sea Level	(fpm)	1270
One Enginer at 5000 feet	(fpm)	136
Service Ceiling (100 ft/min R/C, 7000 lb gross wt)		
Two Engines	(ft)	29,000
One Engine	(ft)	12,200
High Speed at 12,000 Ft	(mph)	235

Maximum Range (No allowance for warm-up, taxi, take-off or climb to altitude. No reserve)

		137 Gal	230 Gal
65% Power at 10,000 ft	(mi)	845	1400
Cruise speed	(mph)	207	207
45% Power at 15,200 ft	(mi)	980	1650
Cruise speed	(mph)	178	1178

Endurance (No allowance for warm-up, taxi, take-off or climb to altitude. No reserve).

		137 gal	230 Gal
65% Power at 10,000 ft	(hr)	4.10	6.8
45% Power at 15,200 ft	(hr)	5.14	9.2

Landing Weight	(lb)	7000
Minimum Landing Distance (Full Flaps-30°)(No Wind)		
Ground Roll	(ft)	1000
Total over 50 ft obstacle	(ft)	1840

6.6 J-50 Airworthiness Certification

The modifications and/or additions to the J-50 will comply with current FAA requirements for this airplane catagory. The FAA has been contacted and knows the general extent of the program. Continuous liaison will be maintained with the FAA so that requirements will be met before certification is requested.

Human Factors

Current crew comfort and safety features will be preserved. The displays and system controls for the new equipment will comply with the concepts of human engineering. The co-pilot will have sufficient conventional equipment.

Performance and Flying Qualities

Minimum flight and ground handling characteristics throughout the existing envelope will remain unchanged.

Strength

The modifications and/or additions to structure will comply with current requirements and will be fully substantiated by strength analysis and/or proof load reports where required.

7.0 FACTUAL DATA - TEST PROGRAM

Testing of the equipments to be installed will be accomplished on three levels: Component testing upon receipt from the Government, the vendor, or the Douglas Production Facility; system testing upon installation in the aircraft; and flight testing.

Equipment installation and structural modifications will be substantiated by strength analysis. Proof load testing will be performed where required for FAA airworthiness certification.

7.1 Component testing of Government and Vendor Furnished Equipment will be performed in accordance with test procedures and equipment furnished by the government or by the vendor of the equipment. This testing will assure that the units are acceptable upon arrival at Douglas.

7.2 System Bench Testing will be performed in the aircraft, first on a sub-system basis, and then on a total system basis. Use of the aircraft as the bench saves the expense of duplicating of wiring harnesses, saves time in checking out aircraft power and wiring systems, and brings out electrical interference problems at an early stage of the program

7.3 Flight Testing will be limited to that required for the aircraft to prove airworthiness and that required for the system to prove it to be operational. System evaluation will be conducted by the Army.

8.0 Program schedule information is presented in Exhibit 30.

9.0 CONCLUSIONS

The Advanced Army Aircraft Instrumentation System as defined herein will represent a significant improvement in aircraft instrumentation. The design of this system has advanced to the point of finalization of equipment specifications and, upon approval of the Army, the letting of subcontracts to obtain the equipment.

Two significant problems which occurred during the Design Plan phase are:

(1) The difficulty in obtaining the reduction factor of 270X for map information as originally proposed to put a 1000 X 1000 NM map on a $4\frac{1}{2}$ X $4\frac{1}{2}$ slide. This problem has been resolved by changing the map storage to 70mm film strips involving a reduction factor of 10X.

(2) The determination of map projection and map content to be used. The projection problem was resolved by assuring that the computer will handle any map projection transformation. The decision on map content is being jointly worked upon by Douglas and USASRDL.

10.0 PROGRAM FOR NEXT INTERVAL

The program for the next reporting period, contingent upon the contract Item 1 Design Plan approval and authorization to proceed with Items 2 thru 6, will consist of the following:

(a) Vendor coordination effort for finalization of the respective equipment specifications.

(b) Formalization of the respective sub-contracts for submittal to the Army for approval.

(c) Detail equipment and aircraft installation design.

(d) Rework of J-50 aircraft for installation of the system components.

11.0 Identification of Key Technical Personnel

V. D. KIRKLAND

Assistant Chief Design Engineer, Avionics, Aircraft Division

Education: B.S., Purdue University, 1948; M.S., University of Notre Dame in 1950.

Mr. Kirkland joined the Douglas Company shortly after graduation. His present position of Assistant Chief Design Engineer was reached through experience as design specialist, aircraft automatic controls; design specialist, missile guidance; chief, analog computing facility, and section chief, missile guidance. Mr. Kirkland's specialty is in the field of electronic automatic flight control systems.

E. L. WITTEN

Chief, Navigation and Displays Section, Aircraft Division

Education: B.S., Electrical Engineering, University of Louisville, Kentucky, 1943.

Mr. Witten has been employed by Douglas Aircraft since graduation on assignment such as radar and communication equipment evaluation, design of remote control equipment and integral airplane antenna systems, vendor coordination and system evaluation of the AERO X24A fire control system, avionic proposals for the XVA airplane and the Eagle missile system. He is chief of the Navigation Display Section which is responsible for the weapons and navigation and instrumentation systems on the A4D airplane, the photographic system on the A3D airplane, and instrumentation and navigation systems on commercial aircraft.

W. R. MORELAND

Assistant Chief, Navigation and Displays Section

Education: B.S., Electrical Engineering, Illinois Institute of Technology, 1954; M.S., Electrical Engineering, California Institute of Technology, 1955.

Since 1955, Mr. Moreland has handled numerous areas of design effort for Douglas, including power boost and Full power aircraft control system design, autopilot and automatic air-to-air Fire Control system synthesis, analog computer simulation studies, advanced aircraft systems proposal studies, and missile automatic control systems. He was responsible for the analysis and applicability study of an inertial navigation system for light-weight, high performance aircraft.

Since 1959, he has engaged in various ASW projects, including technical responsibility for the design and development of an automatic signal data analyzer for submarine explosive echo ranging Fire Control Systems. His present position is Systems Engineer for ASW and Weapons Systems.

While still in school, Mr. Moreland accomplished work for the Barber-Colman Company, acquiring a well rounded background in electro-mechanical actuators and aircraft automatic control systems.

J. H. KENDALL

Design Specialist - Navigation and Display Section

Mr. Kendall employed by Douglas since 1952, has devoted his efforts almost exclusively to thefield of weapons system design, analysis, and control. Major programs responsibilities have included analog computer simulation of the complete Aero X24A/F5D-1 Fire Control System, design of radar display simulators for human factors studies, F6D-1 Eagle Missile Control System, and A3D-2Q Doppler Navigation System. He has also been involved in every major proposal effort since he came to Douglas which includes both aircraft and missile weapons systems. His present job is head of the Design and Installation Group of the Navigation and Display Section.

J. N. CAHOW

Design Specialist, Navigation and Displays Section

Education: B.S., Electrical Engineering, Duke University.

Mr. Cahow joined Douglas in 1950 after 2 years with U. S. Electrical Motors in the design and testing of induction motors. His experience at Douglas includes 3 years of aircraft radio and power system design, installation and testing; and 7 years of equipment integration, design, and testing of airborne electronic fire control, navigation, and bombing systems. He specializes in controls and displays for electronic systems.

V. E. HAMILTON

Design Specialist, Navigation and Display Section, Aircraft Division

Education: Studied Psychology, University of Southern California; Space Technology, Modern Engineering Physics, University of California at Los Angeles; Human Relations in Management, Loyola University.

Mr. Hamilton joined the Douglas Company in 1939. In 1955, Mr. Hamilton specialized in optics by taking special courses, and later developed collimated sights and pilot display projection optics.

Further technical contributions by Mr. Hamilton include:

Optical detectors for biological and chemical warfare devices.

Gunsight and cathode-ray tube (CRT) optical projectors.

Engineered Optical development for surveillance satellite.

Directed special development of instrument lighting and dichroic coatings on optical surfaces.

Invented special ambient light-trapping filters for CRT and electroluminescent panels.

Several articles by Mr. Hamilton have appeared recently in technical magazines.

He is a past president of the American Optical Society.

AD-

Aircraft Div., Douglas Aircraft Company
Long Beach, California
ON THE ADVANCED ARMY AIRCRAFT INSTRUMENTATION SYSTEM DESIGN PLAN (UNCLASSIFIED) by J. N. Cahow, R. A. Lennel and others. Quarterly Rept. No. 1 Jun 62. 151p. incl. illus. tables. (Tech. Quarterly Rpt. No. 1.) (Contract DA-36-039SC(87354) (Uncl. report)

The Design Plan is the first phase of the Advanced Army Aircraft Instrumentation System program during which system requirements and equipment parameters were established for an integrated pictorial display system based on present Army Navy Instrumentation Program (ANIP) concept. A digital Computer, display

(over)

UNCLASSIFIED

1. T.V. Displays
2. Display Generation
3. Airborne Sensors
I. Title: ANIP
II. Douglas Aircraft Company, Inc.
III. Army Signal Corps Ft.Monmouth,N.J.
IV. Contract DA-36-039SC(87354)
V. Douglas Report No. ES 40634A

UNCLASSIFIED

AD-

Aircraft Div., Douglas Aircraft Company
Long Beach, California
ON THE ADVANCED ARMY AIRCRAFT INSTRUMENTATION SYSTEM DESIGN PLAN (UNCLASSIFIED) by J. N. Cahow, R. A. Lennel and others. Quarterly Rept. No. 1 Jun 62. 151p. incl. illus. tables. (Tech. Quarterly Rpt. No. 1.) (Contract DA-36-039SC(87354) (Uncl. report)

The Design Plan is the first phase of the Advanced Army Aircraft Instrumentation System program during which system requirements and equipment parameters were established for an integrated pictorial display system based on present Army Navy Instrumentation Program (ANIP) concept. A digital Computer, display

(over)

UNCLASSIFIED

1. T.V. Displays
2. Display Generation
3. Airborne Sensors
I. Title: ANIP
II. Douglas Aircraft Company, Inc.
III. Army Signal Corps Ft.Monmouth,N.J.
IV. Contract DA-36-039SC(87354)
V. Douglas Report No. ES 40634A

UNCLASSIFIED

AD-

Aircraft Div., Douglas Aircraft Company
Long Beach, California
ON THE ADVANCED ARMY AIRCRAFT INSTRUMENTATION SYSTEM DESIGN PLAN (UNCLASSIFIED) by J. N. Cahow, R. A. Lennel and others. Quarterly Rept. No. 1 Jun 62. 151p. incl. illus. tables. (Tech. Quarterly Rpt. No. 1.) (Contract DA-36-039SC(87354) (Uncl. report)

The Design Plan is the first phase of the Advanced Army Aircraft Instrumentation System program during which system requirements and equipment parameters were established for an integrated pictorial display system based on present Army Navy Instrumentation Program (ANIP) concept. A digital Computer, display

(over)

UNCLASSIFIED

1. T.V. Displays
2. Display Generation
3. Airborne Sensors
I. Title: ANIP
II. Douglas Aircraft Company, Inc.
III. Army Signal Corps Ft.Monmouth,N.J.
IV. Contract DA-36-039SC(87354)
V. Douglas Report No. ES 40634A

UNCLASSIFIED

AD-

Aircraft Div., Douglas Aircraft Company
Long Beach, California
ON THE ADVANCED ARMY AIRCRAFT INSTRUMENTATION SYSTEM DESIGN PLAN (UNCLASSIFIED) by J. N. Cahow, R. A. Lennel and others. Quarterly Rept. No. 1 Jun 62. 151p. incl. illus. tables. (Tech. Quarterly Rpt. No. 1.) (Contract DA-36-039SC(87354) (Uncl. report)

The Design Plan is the first phase of the Advanced Army Aircraft Instrumentation System program during which system requirements and equipment parameters were established for an integrated pictorial display system based on present Army Navy Instrumentation Program (ANIP) concept. A digital Computer, display

(over)

UNCLASSIFIED

1. T.V. Displays
2. Display Generation
3. Airborne Sensors
I. Title: ANIP
II. Douglas Aircraft Company, Inc.
III. Army Signal Corps Ft.Monmouth,N.J.
IV. Contract DA-36-039SC(87354)
V. Douglas Report No. ES 40634A

UNCLASSIFIED

AD-

generator, vertical and horizontal television display, and sensors (i.e. velocity, attitude, altitude, directional, terrain avoidance,etc.) have been integrated into an ANIP system to satisfy the requirements for advanced ASR-2 and ASR-3 type aircraft. The system defined is adaptable to any type of manned vehicle.

UNCLASSIFIED

UNCLASSIFIED

AD-

generator, vertical and horizontal television display, and sensors (i.e. velocity, attitude, altitude, directional, terrain avoidance,etc.) have been integrated into an ANIP system to satisfy the requirements for advanced ASR-2 and ASR-3 type aircraft. The system defined is adaptable to any type of manned vehicle.

UNCLASSIFIED

UNCLASSIFIED

AD-

generator, vertical and horizontal television display, and sensors (i.e. velocity, attitude, altitude, directional, terrain avoidance,etc.) have been integrated into an ANIP system to satisfy the requirements for advanced ASR-2 and ASR-3 type aircraft. The system defined is adaptable to any type of manned vehicle.

UNCLASSIFIED

UNCLASSIFIED

AD-

generator, vertical and horizontal television display, and sensors (i.e. velocity, attitude, altitude, directional, terrain avoidance,etc.) have been integrated into an ANIP system to satisfy the requirements for advanced ASR-2 and ASR-3 type aircraft. The system defined is adaptable to any type of manned vehicle.

UNCLASSIFIED

UNCLASSIFIED

13.0 DISTRIBUTION LIST

U. S. ARMY SIGNAL R&D LABORATORY
Fort Monmouth, N. J.

SIGRA/SL-SVN

Distribution List for First Quarterly Report
by Douglas Aircraft Co, Inc.
Contract DA-36-039 SC-87354

No. of Copies	Distribution List
1	OASD(R&E), ATTN: Technical Library, The Pentagon, Washington 25, D. C.
1	Chief of Research and Development, OCS, Department of the Army, Washington 25, D. C.
2	Chief, U. S. Army Security Agency, Arlington Hall Station, Arlington 12, Va.
1	Deputy President, U. S. Army Security Board, Arlington Hall Station, Arlington 12, Virginia
1	Chief of Transportation, ATTN: TAFO-D, Department of the Army, Washington 25, D. C.
1	Director, U. S. Naval Research Laboratory, ATTN: Code 2027, Department of the Navy, Washington 25, D. C.
1	Commanding Officer & Director, U. S. Naval Electronics Laboratory, San Diego 52, California
1	Commander, Aeronautical Systems Division, ATTN: ASAPRL, Wright Patterson Air Force Base, Ohio
1	Commander, Aeronautical Systems Division, ATTN: ASNPFC (C. J. Jolly), Wright Patterson Air Force Base, Ohio
1	Commander, Air Force Cambridge Research Laboratory, ATTN: CRO, L. G. Hanscom Field, Bedford, Mass.
1	Commander, Air Force Cambridge Research Laboratory, ATTN: CRZC, L. G. Hanscom Field, Bedford, Mass.
2	Commander, Air Force Cambridge Research Laboratory, ATTN: CCSD, L. G. Hanscom Field, Bedford, Mass.
1	Commander, Rome Air Development Center, ATTN: RAALD, Griffiss Air Force Base, N. Y. 1
1	Commanding General, U. S. Army Electronic Proving Ground, ATTN: Technical Library, Fort Huachuca, Arizona
1	Director, U. S. Army Board of Aviation Accident Research, Fort Rucker, Ala.
1	President, U. S. Army Aviation Board, Fort Rucker, Alabama
10	Commander, Armed Services Technical Infromation Agency, ATTN: TIPCA, Arlington Hall Station, Arlington 12, Va.
1	Commanding Officer, U. S. Army Transportation Materiel Command, ATTN: L. A. Bell, Air Br, Stnd Div, P. O. Box 209, St Louis, Missouri
1	Commanding Officer, U. S. Army Engineer Geodesy, Intelligence Mapping Research and Development Agency, ATTN: ENGGM-SS (Tredwell) Fort Belvoir, Va.

No. of Copies	Distribution List (contd)
1	AFSC Liaison Office, Naval Air R&D Activities Command, Johnsville, Penna.
3	U. S. Continental Army Command Liaison Officer, U. S. Army Signal R&D Laboratory, Fort Monmouth, N. J.
1	Corps of Engineers Liaison Office, U. S. Army Signal R&D Laboratory, Fort Monmouth, N. J.
2	Marine Corps Liaison Office, U. S. Army Signal R&D Laboratory, Fort Monmouth, N. J.
1	Commanding Officer, U. S. Army Signal R&D Laboratory, ATTN: Director of Engineering, Fort Monmouth, N. J.
3	Commanding Officer, U. S. Army Signal R&D Laboratory, ATTN: Chief, Technical Information Division, Fort Monmouth, N. J.
9	Commanding Officer, U. S. Army Signal R&D Laboratory, ATTN: SIGRA/SL-SVN, Fort Monmouth, N. J.

This contract is supervised by Mr. Billy L. Gibson, Navigation & Flight Aids Branch, Avionics Division, Surveillance Department, U. S. Army Signal R&D Laboratory, Fort Monmouth, N. J., telephone 201-59-61415.